This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

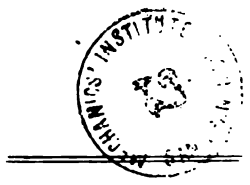
+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

North
3-VHA

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.



TRANSACTIONS.

VOL. X.

REPORT OF THE PROCEEDINGS OF THE MEETING AT BIRMINGHAM, JULY 16TH, 17TH, AND 18TH, 1861.

NEWCASTLE-ON-TYNE: ANDREW REID, 40 & 65, PILGRIM STREET.

1862.

173222

NEWCASTLE-UPON-TYNE:
PRINTED BY ANDREW REID, 40 & 65, PILGRIM STREET.

INDEX TO VOL. X.

A

Address by the President 3
America, English Coal used in 41 60
Anemometers, Experiments with 214 227 237 238
Arenaceous Strata, how bored 199
Atkinson, J. J., on the Ninety-Fathom Dyke 116
Atkinson, J. J., on Air Currents in Mines 207 241
Aytoun, Robert, on Safety Cages 89

B

Biram's Anemometer 214
Bailey, S., on Underground Steam Engines 28
Beale, Mr., Remarks on Combustion 179
Belgian Coal, French Duty on 60
Berkley, C., on Safety Cages 93
Blackwell, Mr., Remarks on Combustion .. .. 167 to 197
Blaydon Coal—its quality 50
Blyth District, Coal in 42
Boyd, E. F., on Overlying Limestone 115 117
Bristol Coal District 98 104

C

Currents of Air in Mines 207 242
Combes' Anemometer 227
Combustion, Spontaneous 179
Cossham, H., on Bristol Coal 97
Cheshire Coal, statements as to 66
Cinderhill Colliery, description of 149
Clay, Mr., on Tubbing 199

DUP. EXCHANGE, 28 APR. 1902

CHANIC'S INST. LIB.

N.Y. PUBLIC LIBRARY EXCHANGE. FORD COLLECTION.

Cossham, H., on Long Wall Working 142 144
Cossham, H., on Spontaneous Combustion 172
Catch, disengaging, for Safety Cage 90
Coal raised in South Staffordshire 194
Cages used in the North 53
Comparison of Anemometers 227

D

Dickinson's Anemometer 238
Discussion on Bristol Coal 115
Drainage of Inundated Collieries 50
Daglish, J., on Safety Cages 93 95
Daglish, J., on Spontaneous Combustion 178
Derbyshire Coal District 66 117
Duration of Northern Coal Field 61
Duration of Bristol Coal Field 102
Darlington, J., on Spontaneous Ignition 180
Damming after Side Work 190
Derbyshire Coal Mining, by J. T. Woodhouse 117

E

Evans, Mr., on Spontaneous Ignition 179

F

French Duty on Belgian Coal 60
Fire-stink, or Sulphuretted Hydrogen 192
Fires in Mines, how extinguished 180
Freight on Coal to New York 60

G

Greenwell, G. C., on Bristol Coal 98 115
Gloucestershire Coal 66
Guide Rods 125
Gunpowder, use of, in Air Currents 210

H

Hydrogen, Sulphuretted 192
Hall, T. Y., on Northern Coal-field, &c. 41
Henaut's Anemometer 238

Howard, W. F., on Buxton's Ventilation Register, &c. 133
Hunt, Robert, his Mining Statistics 71

I

Inaugural Address, Mr. Wood's 3
Ignition, Spontaneous 167 172 177 198
Inundated Collieries on the Tyne 47 50
Ireland, Coal Produce of 66
Ironstone, Staffordshire 25 120
Ironstone, North of England 62

J

Johnson, Henry, on Mining in Staffordshire 183
Johnson, Henry, on Spontaneous Ignition 197

K

Knife to cut Old Tubing 202

L

Lind's Anemometer 237
Long Wall Working 127 137 142
Lamp, Stephenson's, preferred 126
Landale, Andrew, on Safety Cages 94
London, Coal sent to 72
Long Wall Working, Mr. Potter on 138

M

Mining Science in the North of England 6
Moira Colliery, Spontaneous Combustion at .. 164 167 198
Murton Colliery, Expense of Winning 52
Matthews, Mr., moves thanks to Mr. Wood 245

N

North of England Coal-field, Limits of 44
North of England Coal District, Statements as to 75
Northern Coal-field, T. Y. Hall on the 41 47 61

O

Old Firing Line 194

Ordnance Maps of Bristol Coal-field 103 110
Osler's Anemometer 236

P

Probable Results of Birmingham Meeting 6
Probable Duration of Coal-fields 61 102 109
Parkhead Colliery, Section of 195
Patent Fuel exported 70
Potter, Edward, on the River Tyne 34
Pyrites, Spontaneous Ignition of 168 180 196

Q

Quicksands, how got through 199

R

Results of the Meeting at Birmingham, probable 6
Reid, P. S., on Tubing Bore-holes 199
Robinson's Anemometer 228 236
Revolving Anemometers 216

S

Science, Mining, in the North of England 6
Sandy Strata, Management of 199
Spontaneous Combustion, J. J. Atkinson on 177 180
Spontaneous Combustion, Remarks on, by Messrs. Blackwell, Birkenhead, &c. 167 172 177 198
Steam Coal 42
Spontaneous Ignition, E. F. Boyd on 172
Safety Cages, Remarks on 88 90
Smith, Stuart, on Spontaneous Ignition 178
Stephenson's Lamp used 126
Scotland, Coal raised in 66

T

Tubbing, Method of 199 200
Tubs introduced in Northumberland 53
Tubing Bore-holes, Discussion on 247

U

Underground Steam Haulage 25

Ure, Mr., Improvements of the Tyne 49

V

Velocity of Currents of Air 207 241
Ventilation Register, Buxton's 133
Ventilation, Mining 207

W

Wood, Nicholas, Address 3
Whewell's Anemometer 237
Woodhouse, J. T., on Spontaneous Ignition 175
Woodhouse, J. T., on the Derby Coal-field 137
Woodhouse, J. T., on the Mining of Derbyshire 117
Wales, Coal raised in 66
Warwickshire Produce of Coal 66
Water in the Inundated Tyne Collieries 46
Worcestershire, Coal raised in 66
Wynne, Mr., on the Long Wall System 144
Whirling Machine, Experiments with 226 230

ADVERTIZEMENT.

THE Institution is not, as a body, responsible for the facts and opinions advanced in the Papers read, and in the Abstracts of the Conversations which occurred at the Meetings during the Session.

Patrons.

His Grace the Duke of Northumberland.
The Right Honourable the Earl of Lonsdale.
The Right Honourable the Earl Grey.
The Right Honourable the Earl of Durham.
The Right Honourable Lord Wharncliffe.
The Right Honourable Lord Ravensworth.
The Right Reverend the Lord Bishop of Durham.
The Very Reverend the Dean and Chapter of Durham.
The Venerable Archdeacon Thorpe, the Warden of Durham University.
Wentworth B. Beaumont, Esq., M.P.

OFFICERS, 1862-63.

President.

NICHOLAS WOOD, Hetton Hall, Fence Houses.

Vice-Presidents.

WILLIAM ANDERSON, Cleadon Cottage, South Shields.
EDWARD POTTER, Cramlington, Newcastle.
J. T. WOODHOUSE, Midland Road, Derby, Derbyshire.
THOMAS E. FORSTER, 7, Ellison Place, Newcastle-on-Tyne.

Council.

CUTHBERT BERKLEY, Marley Hill Colliery, Gateshead.
THOMAS G. HURST, Backworth Colliery, Newcastle-upon-Tyne.
JOHN R. LIDDELL, Netherton Colliery, Morpeth.
JOHN DAGLISH, Hetton Colliery, Fence Houses.
JOHN MARLEY, Mining Offices, Darlington.
P. S. REID, 53, Westgate Street, Newcastle-on-Tyne.
GEORGE W. SOUTHERN, Rainton Colliery, Fence Houses.
JOHN T. RAMSAY, Walbottle Colliery, Newcastle-on-Tyne.
S. C. CRONE, Killingworth Colliery, Newcastle.
T. DOUGLAS, Pease's West Collieries, Darlington.
G. B. FORSTER, Cowpen Lodge, Blyth.
JOHN BELL SIMPSON, Moor House, Ryton, Newcastle.

Treasurer.

EDWARD F. BOYD, Moor House, Durham.

Secretary.

THOMAS DOUBLEDAY, Newcastle.

Honorary Members.

John Alexander, Esq., Inspector of Mines, Glasgow.
John J. Atkinson, Esq., Inspector of Mines, Bowburn, Durham.
Lionel Brough, Esq., Inspector of Mines, Clifton, Bristol, Somersetshire.
Joseph Dickinson, Esq., Inspector of Mines, Manchester, Lancashire.
Matthias Dunn, Esq., Inspector of Mines, 5, St. Thomas Place, Newcastle-on-Tyne.
Thomas Evans, Esq., Inspector of Mines, Richmond Villas, Swansea.
Goldsworthy Gurney, Esq., Bude Castle, Cornwall.
John Hedley, Esq., Inspector of Mines, Derby, Derbyshire.
Peter Higson, Esq., Inspector of Mines, 94, Cross Street, Manchester.
Charles Morton, Esq., Inspector of Mines, Wakefield, Yorkshire.
Thomas Wynne, Esq., Inspector of Mines, Longton, North Staffordshire.
M. de Boureuille, Commander de la Legion d'Honneur, Conseiller d'état Inspector General of Mines, Paris, France.
Dr. H. Von Dechen, Berghauptmann, Ritter, &c., Bonn on the Rhine, Prussia.
Herr R. Von Carnall, Berghauptmann, Ritter, &c., Breslau, Silesia, Prussia.
M. de Vaux, Inspector General of Mines, Brussels, Belgium.
M. Gonot, Mining Engineer, Mons, Belgium.

Life Member.

H. J. Morton, Esq., Garforth House, Leeds, Yorkshire.

List of Members.

1 Adams, W., Ebw Vale Works, Newport, Monmouthshire.
2 Anderson, W., Cleadon Cottage, South Shields, County of Durham.
3 Anderson, C. W., St. Hilda's Colliery, South Shields, County of Durham.
4 Appleby, Charles Edward, 3, London Terrace, Derby, Derbyshire.
5 Arkless, B., Tantoby, Gateshead, County of Durham.
6 Armstrong, W., Wingate Grange, Ferry Hill, County of Durham.
7 Ashwell, Hatfield, Anchor Colliery, Longton, North Staffordshire.
8 Atkinson, J., Gaveller's Office, Coleford, Gloucestershire.
9 Attwood, Charles, Towlaw, Darlington, County of Durham.
10 Aytoun, Robert, 3, Fetter Row, Edinburgh.

11 Bagnall, Jun., Thomas, Whitby, Yorkshire.
12 Bailes, Jun., Thos., Hematite Iron Works Collieries, Cleator Moor, Whitehaven.
13 Bailey, W. W., Kilburn, near Derby, Derbyshire.
14 Bailey, Samuel, The Pleck, Walsall, Staffordshire.
15 Barkus, W., Low Fell, Gateshead, County of Durham.
16 Barkus, Jun., Wm., Broom Hill Colliery, Acklington.
17 Barrow, Richard, Ringwood Hall, Chesterfield, Derbyshire.
18 Bartholomew, C., Doncaster, Yorkshire.
19 Bassett, A., Tredegar Mineral Estate Office, Cardiff, Glamorganshire.
20 Beacher, E., Thorncliffe and Chapeltown Collieries, Sheffield, Yorkshire.
21 Beckett, W. Henry, Penn, Wolverhampton, Staffordshire.
22 Bell, John, Normanby Mines, Middlesbro'-on-Tees.
23 Bell, I. L., Washington, Gateshead, County of Durham.

24 Bell, T., Shincliffe Colliery, near Durham.
25 Berkley, C., Marley Hill Colliery, Gateshead, County of Durham.
26 Bewick, J., Executors of, Grosmont, Whitby, Yorkshire.
27 Bewick, Thomas J., Allenheads, Haydon Bridge, Northumberland.
28 Bigland, J., Bedford Lodge, Bishop Auckland, County of Durham.
29 Binns, C., Claycross, Derbyshire.
30 Blackwell, John Kenyon, 73, Gloucester Terrace, Hyde Park, London, W.
31 Bolckow, H. W. F., Middlesbro'-on-Tees, Yorkshire.
32 Bourne, P., Whitehaven, Cumberland.
33 Bourne, S., West Cumberland Hematite Iron Works, Workington.
34 Bourne, Thos. R., Peaseley Cross, St. Helen's, Lancashire.
35 Bowkley, Silas, Batman's Hill, Bilston, Staffordshire.
36 Boyd, Edward F., Moor House, Durham.
37 Braithwaite, Thomas, Eglinton Iron Works, Kilwinning, Ayrshire.
38 Briggs, Henry C., Outwood Hall, Wakefield.
39 Brogden, James, Tondû Iron and Coal Works, Bridge End, South Wales.
40 Brown, J., Bank Top, Darlington, County of Durham.
41 Brown, J., Harbro' House, Barnsley, Yorkshire.
42 Brown, J., Whitwell Colliery, County of Durham.
43 Brown, John N., 56, Union Passage, New Street, Birmingham.
44 Brown, Thos. Forster, Machen, Newport, Monmouthshire.
45 Brigham, William, Rose Bridge, Wigan, Lancashire.
46 Buxton, William, Staveley Colliery, Chesterfield, Derbyshire.

47 Cadwalader, R., Broughton Colliery, Wrexham, Denbighshire.
48 Carr, Charles, Cramlington, Newcastle-on-Tyne.
49 Carr, William Cochrane, Blaydon, Newcastle.
50 Carrington, Jun., Thomas, 15, Osmaston Road, Derby, Derbyshire.
51 Charlton, G., Dunkirk Collieries, Dukenfield, near Manchester.
52 Childe, Rowland, Wakefield, Yorkshire.
53 Clark, W. S., Aberdare, Glamorganshire.
54 Cochrane, W., 42, Leazes Terrace, Newcastle-on-Tyne.
55 Cochrane, C., Woodside Iron Works, near Dudley.
56 Cockburn, William, Hutton Low Cross Mines, Guisbro', Yorkshire.
57 Coke, Richard George, Tapton Grove, Chesterfield, Derbyshire.
58 Cole, W. R., Bebside Colliery, Morpeth.
59 Collis, William Blow, The Platts, Stourbridge, Worcestershire.

60 Cook, Richard, East Holywell Colliery, Earsdon, Newcastle.
61 Cooke, John, Willington Colliery, Durham.
62 Cooper, Philip, Rotherham Colliery, Rotherham, York.
63 Cope, J., King Swinford, Dudley, Worcestershire.
64 Cordner, Richard, Crawlaw House, Stanhope, Weardale.
65 Cossham, H., Shortwood Lodge, Bristol, Somersetshire.
66 Coulson, W., Crossgate Foundry, Durham.
67 Cowen, Jun., Jos., Blaydon Burn, Newcastle.
68 Coxon, F., Shelton Collieries Iron Works, Stoke-on-Trent, Staffordshire.
69 Coxon, S. B., Usworth Colliery, Gateshead.
70 Crawford, T., Church Street, Durham.
71 Crawford, Jun., T., Little Town Colliery, Durham.
72 Crawhall, G. E., St. Ann's Rope Works, Newcastle-on-Tyne.
73 Crawshay, Edwin, Abbott's Works, Newnham, Gloucestershire.
74 Creswick, Theophilus, Clymnel, Merthyr Tydvil, Glamorganshire.
75 Crofton, J. G., Crook, Darlington.
76 Crone, S. C., Killingworth Colliery, Newcastle.
77 Curry, Thomas, Cassop Colliery, Ferry Hill.

78 Daglish, J., Hetton Colliery, Fence Houses.
79 Dakers, Thomas, Byers Green, Ferry Hill.
80 Darlington, James, Springfield House, Coppull, near Chorley, Lancashire.
81 Davison, A., Hastings Cottage, Seaton Delaval, Newcastle.
82 Davidson, James, Newbattle Colliery, Dalkeith.
83 Deane, John, Pencaitland Colliery, Tranent, Haddingtonshire, North Britain.
84 Dees, J., Whitehaven, Cumberland.
85 Dickinson, W. R., Pease's West Collieries, Darlington.
86 Dixon, George, Whitehaven, Cumberland.
87 Dobson, S., Halswell Terrace, Cardiff, Glamorganshire.
88 Dodd, Benj., Blaenavon, Newport, Monmouthshire.
89 Douglas, T., Pease's West Collieries, Darlington.
90 Dunn, T., Richmond Hill, Sheffield, Yorkshire.
91 Dunn, C.E., Thomas, Windsor Bridge Iron Works, Manchester, Lancashire.

92 Easton, J., Nest House, Gateshead.
93 Elliot, G., Houghton-le-Spring, Fence Houses.

94 Elliott, W., Weardale Iron Works, Towlaw, Darlington.
95 Embleton, T. W., Middleton Hall, Leeds, Yorkshire.
96 Errington, C.E., ——, Executors of, Westminster, London, S.W.

97 Feare, G., Camerton Coal Works, Bath.
98 Fletcher, C.E., Jos., Dawson Place, Whitehaven, Cumberland.
99 Fletcher, John, Clifton Colliery, Manchester, Lancashire.
100 Foord, J. B., General Mining Association Secretary, 52, Broad Street, London.
101 Forster, J. H., Old Elvet, Durham.
102 Forster, G. B., Seaton Delaval, Newcastle.
103 Forster, Thomas E., 7, Ellison Place, Newcastle-on-Tyne.
104 Fothergill, Joseph, Cowpen Office, Quay, Newcastle-on-Tyne.
105 Fowler, George, Moira Collieries, Ashby-de-la-Zouch, Leicestershire.
106 Fryar, Mark, Eighton Moor Colliery, Gateshead.

107 Gainsford, William Dunn, Derby.
108 Gardner, M. B., Chilton Colliery, Ferry Hill.
109 Gibsone, Edmund, Penton, Longtown, Carlisle.
110 Gillett, F. C., 5, Wardwick, Derby.
111 Gilroy, G., Ince Hall Colliery, Wigan, Lancashire.
112 Goddard, C.E., William, Longton, North Staffordshire.
113 Gooch, G. H., Lintz Colliery, Gateshead.
114 Greaves, G. O., Horbury, Wakefield, Yorkshire.
115 Green, G. H., Rainton Colliery, Fence Houses.
116 Green, Jun., Wm., Framwellgate Colliery, Durham.
117 Greener, W , Pemberton Colliery, Wigan, Lancashire.
118 Greenwell, G. C., Radstock Colliery, Bath, Somersetshire.

119 Haggie, P., Gateshead.
120 Hall, T. Y., 11, Eldon Square, Newcastle.
121 Hall, William F., Kelloe Colliery, Ferry Hill.
122 Hall, Thomas, West Hetton Colliery, Ferry Hill.
123 Hann, W., Hetton, Fence Houses.
124 Harden, J. W., Exhall Colliery, Coventry, Warwickshire.
125 Harris, James, Surveyor, Hanwell, Middlesex.
126 Harrison, C.E., T. E., Central Station, Newcastle.
127 Harrison, ——
128 Hawthorn, R., Engineer, Newcastle.

129 Hawthorn, W., Engineer, Newcastle.
130 Heardman, John, Bebside Colliery, Morpeth.
131 Heath, Robert, Newcastle-under-Lyme, Staffordshire.
132 Heckels, R., Bunker's Hill, Fence Houses.
133 Hedley, Edward, Oriel Terrace, Gerard Street, Derby.
134 Hetherington, David, Howard's West Hartley Colliery, Netherton, near Morpeth.
135 Hewlett, Alfred, Haigh Colliery, Wigan, Lancashire.
136 Higson, Jacob, 94, Cross Street, Manchester.
137 Hodgson, R., Engineer, Whitburn, Monkwearmouth, Sunderland.
138 Hood, Archibald, Whitehill Colliery, Lasswade, Edinburgh.
139 Horsley, Jun., W., Seaton Cottage, Hartley, Newcastle.
140 Horton, T. E., Prior's Lea Hall, Shiffnal, Shropshire.
141 Howard, Wm. Frederick, Staveley Works, Chesterfield, Derbyshire.
142 Hunt, J. P., Corngreaves, Birmingham, Warwickshire.
143 Hunter, Wm., Spital Tongues, Newcastle.
144 Hunter, William, Morriston, Swansea, Glamorganshire.
145 Hurst, T. G., Backworth Colliery, Newcastle-on-Tyne.

146 Jackson, Frederick John, Seaton Delaval, Newcastle.
147 Jackson, Henry, Astley and Bedford Collieries, Tyldesley, Manchester.
148 Jackson, John, 90, Green Lane, Derby.
149 James, Christopher, Mountain Ash Colliery, Aberdare, Glamorganshire.
150 Jeffcock, P., Midland Road, Derby.
151 Jobling, T. W., Point Pleasant, Wallsend, Newcastle.
152 Johnson, J., Chilton Hall, Ferry Hill.
153 Johnson, R. S., Haswell, Fence Houses.
154 Johnson, Wm. Henry, Dudley, Worcestershire.
155 Joicey, James, Quay, Newcastle.
156 Joicey, John, Urpeth Lodge, Fence Houses.
157 Jones, E., Granville Lodge, Wellington, Salop.
158 Jones, Alex., Mine Agent, Prior's Lee, near Shiffnal, Shropshire.

159 Kerr, John, Auchinheath, Leshmahagow, North Britain.
160 Kimpster, W., Quay, Newcastle.
161 Knowles, A., High Bank, Pendlebury, Manchester, Lancashire.
162 Knowles, John, Pendlebury, Manchester, Lancashire.
163 Knowles, Thomas, Ince Hall, Wigan, Lancashire.

164 Lancaster, John, Kirkless Hall Coal and Iron Works, Wigan, Lancashire.
165 Landale, Andrew, Lochgelly, Fifeshire, North Britain.
166 Laverick, George, Plymouth Iron Works, Merthyr Tydvil, Glamorganshire.
167 Laws, J., Blyth, Northumberland.
168 Lever, Ellis, West Gorton Works, Manchester.
169 Levick, Jun., F., Cwm Celyn and Blaina Iron Works, Newport, Monmouthshire.
170 Lewes, T. Wm., Plymouth Iron Works, Merthyr Tydvil, Glamorganshire.
171 Liddell, J. R., Netherton Colliery, Morpeth.
172 Liddell, M., Hedgefield House, Stella, Gateshead.
173 Lindop, James, Bloxwich, Walsall, Staffordshire.
174 Lishman, Wm., Etherley Colliery, Darlington.
175 Lishman, Wm., Lumley Colliery, Fence Houses, Durham.
176 Little, William, West Cramlington, Newcastle.
177 Livesey, Thomas, Chamber Hall, Hollinwood, Manchester, Lancashire.
178 Llewellin, Wm., Glanwern, Pontypool, Monmouthshire.
179 Longridge, J., 18, Abingdon Street, Westminster, London, S.W.
180 Love, Joseph, Brancepeth Colliery, Durham.
181 Low, Wm., Vron Colliery, Wrexham, Denbighshire.

182 Maddison, W. P., Thornhill Colliery, Dewsbury, Wakefield.
183 Marley, John, Mining Offices, Darlington.
184 Marshall, Robert, 10, Three Indian Kings Court, Quayside, Newcastle.
185 Mathews, William, Leasowes, near Birmingham, Warwickshire.
186 Matthews, Richd. F., South Hetton Colliery, Fence Houses.
187 May, George, Hetton Colliery, Fence Houses.
188 Mc'Ghie, Thos., British Iron Works, Ruabon, Denbighshire.
189 M'Gill, Robert, Eccleston Villa, St. Helen's, Lancashire.
190 Middleton, J., Davison's Hartley Office, Quay, Newcastle-on-Tyne.
191 Miller, Jun., William, College Street, Whitehaven.
192 Morison, David P., Pelton Colliery, Chester-le-Street.
193 Morris, William, Waldridge Colliery, Chester-le-Street, Fence Houses.
194 Morton, H., Lambton, Fence Houses.

195 Morton, H. T., Lambton, Fence Houses.
196 Muckle, John, Little Town Colliery, Durham.
197 Mulcaster, H., Colliery Office, Whitehaven.
198 Mulvany, Wm. Thos., 1335, Carls Thor, Dusseldorf on the Rhine, Prussia.
199 Mundle, W., Wardrew House, Gilsland, Northumberland.
200 Murray, T. H., Chester-le-Street, Fence Houses, Durham.

201 Napier, Colin, Westminster Colliery, Wrexham, Denbighshire.

202 Palmer, A. S., Risca Coal Works, near Newport, Monmouthshire.
203 Palmer, C. M., Quay, Newcastle-on-Tyne.
204 Paton, Wm., Alloa Colliery, Alloa, North Britain.
205 Peace, Wm. Maskell, Solicitor, Wigan, Lancashire.
206 Pearce, F. H., Bowling Iron Works, Bradford, Yorkshire.
207 Pease, J. Wm., Woodlands, Darlington.
208 Peele, John, Springwell Colliery, Gateshead.
209 Pilditch, Wm. H., Iron Shipbuilding Yard, Jarrow, South Shields.
210 Pilkington, Jun., Wm., St. Helens, Lancashire.
211 Potter, E., Cramlington, Newcastle-on-Tyne.
212 Potter, W. A., Monk Bretton, Barnsley, Yorkshire.
213 Powell, T., Lower Duffryn Colliery, Aberdare, Glamorganshire.

214 Ramsay, J. T., Walbottle Colliery, Newcastle-on-Tyne.
215 Ramsay, David R., Iron Works, Wallsend.
216 Ravenshaw, J. H., Grange, Newton-in-Cartmel, Lancashire.
217 Rayner, J. T., Methley House, Leeds.
218 Rees, Robert N. T., Letty, Shenkin Colliery, Aberdare, Glamorganshire.
219 Reid, P. S., 53, Westgate Street, Newcastle-on-Tyne.
220 Richardson, Dr., Framlington Place, Newcastle-on-Tyne.
221 Robinson, R., Stanley Colliery, Pease's West, Darlington.
222 Robson, J. G., 22, Brecknock Crescent, Camden Town, London, N.W.
223 Robson, J. S., Butterknowle Colliery, Staindrop, Darlington.
224 Robson, M. B., Field House, Borough Road, Sunderland.
225 Robson, Neil, 18, Park Terrace, Glasgow.
226 Robson, Thomas, Wylam Colliery, Newcastle-upon-Tyne.
227 Rockwell, Alfd. P., M.A., Norwich, Connecticut, United States, America.

228 Rose, Thomas, Coalmaster, Bilston, Wolverhampton, Staffordshire.
229 Ross, A., Shipcote Colliery, Gateshead.
230 Rosser, Wm., Mineral Surveyor, Llanelly, Carmarthenshire, Wales.
231 Rutherford, J., South Tyne Colliery, Haltwhistle, Northumberland.

232 Sanderson, Jun., R. B., West Jesmond, Newcastle-on-Tyne.
233 Sanderson, Thomas, Seaton Delaval, Newcastle.
234 Shield, Hugh, Hetton, Fence Houses.
235 Shore, Isaac, Mineral Surveyor, Grove Bank, near Wrexham, Denbighshire.
236 Shortrede, T., Bourne Moor Colliery, Fence Houses.
237 Shute, Charles A., Thornley Vicarage, Ferry Hill.
238 Simpson, John H., Medomsley Colliery, Gateshead.
239 Simpson, L., Medomsley Colliery, Gateshead.
240 Simpson, R., Ryton, Newcastle.
241 Simpson, John Bell, Moor House, Ryton, Newcastle.
242 Simpson, R. L., Seaton Delaval, Newcastle.
243 Smallman, Joseph Harris, King's Hill, Wednesbury.
244 Smith, C. F. S., Civil and Mining Engineer, Midland Road, Derby.
245 Smith, F., Bridgewater Canal Office, Manchester, Lancashire.
246 Smith, Jun., J., Monkwearmouth Colliery, Sunderland.
247 Smith, Edmund J., 14, Whitehall Place, Westminster, London, S.W.
248 Sopwith, T., 43, Cleveland Square, London, W.
249 Southern, G. W., Rainton Colliery, Fence Houses.
250 Southern, J. M., Kibblesworth Hall, Gateshead.
251 Spark, H. K., Darlington, County of Durham.
252 Spencer, Jun., W., Eston Mines, Middlesbro'.
253 Steavenson, A. L., Normanby Mines, Middlesbro'-on-Tees, Yorkshire.
254 Stenson, W. T., Whitwick Colliery, Ashby-de-la-Zouch, Leicestershire.
255 Stephenson, George R., 24, Great George Street, Westminster, London, S.W.
256 Stobart, Wm., Roker, Monkwearmouth, Sunderland.
257 Stobart, H. S., Witton-le-Wear, Darlington.
258 Stott, G., Ferry Hill, County of Durham.

259 Taylor, H., Earsdon, Newcastle-on-Tyne.
260 Taylor, Jun., H., Backworth Hall, Newcastle-on-Tyne.
261 Taylor, J., Earsdon, Newcastle-on-Tyne.

262 Telford, W., Cramlington, Newcastle-on-Tyne.
263 Thomas, George, Wallend Colliery, Bloxwich, Walsall.
264 Thompson, John, Marley Hill Colliery, Gateshead.
265 Thompson, T. C., Milton Hall, Carlisle, Cumberland.
266 Thomson, Alex., Canonbie Colliery, Hawick, Roxburghshire, N.B.
267 Thorman, John, Ripley, Derbyshire.
268 Thorpe, R. C., North Gawber Colliery, Staincross, Barnsley, Yorkshire.
269 Tone, C.E., John F., 10, Market Street, Newcastle-on-Tyne.
270 Trotter, J., Newnham, Gloucestershire.
271 Truran, Matthew, Dowlais Iron Works, Merthyr Tydvil, South Wales.

272 Vaughan, J., Middlesbro'-on-Tees.
273 Vaughan, Thomas, Middlesbro'-on-Tees.
274 Vaughan, William, Middlesbro'-on-Tees.
275 Verner, Albert, Framwellgate Colliery, Durham.

276 Wales, T. E., 15, Nelson Street, Sunderland.
277 Ward, Henry, Priestfield Iron Works, Oaklands, Wolverhampton.
278 Warden, ——, Birmingham.
279 Ware, W. H., The Ashes, Stanhope, Weardale.
280 Warrington, John, Kippax, near Leeds.
281 Watkin, Wm. John Laverick, Woodifield and Whitelee Collieries, Crook, Darlington.
282 Watson, W., High Bridge, Newcastle-on-Tyne.
283 Watson, Joseph J. W., No. 1, Rue Notre Dame, Passy, near Paris.
284 Webster, R. C., Ruabon Collieries, Ruabon, Denbighshire.
285 Willis, James, Grange Colliery, Durham.
286 Wilmer, F. B., Seaton Colliery, Sunderland.
287 Wilson, J. B., Haydock, near St. Helen's, Lancashire.
288 Wilson, R., Flimby Colliery, Maryport, Cumberland.
289 Wilson, John Straker, Backworth Colliery, near Newcastle.
290 Wood, Charles S., Master of the Mining School, Bristol.
291 Wood, C. L., Black Boy Colliery, Bishop Auckland.
292 Wood, Lindsay, Hetton Colliery, Fence Houses.
293 Wood, N., Hetton Hall, Fence Houses, County of Durham.
294 Wood, W. H., West Hetton, Ferry Hill.
295 Woodhouse, J. T., Midland Road, Derby, Derbyshire.

List of Subscribing Collieries.

Owners of Stella Colliery, Ryton, Newcastle-on-Tyne.
„ Grange Colliery, Durham.
„ Kepier Grange Colliery, Ferry Hill.
„ Leasingthorne Colliery, Ferry Hill.
„ Westerton Colliery, Ferry Hill.
„ Poynton and Worth Colliery.
„ Black Boy Colliery, Bishop Auckland.
„ North Hetton Colliery, Fence Houses.
„ Haswell Colliery, Durham.
„ South Hetton and Murton Collieries, Fence Houses.
„ Earl of Durham, Lambton Collieries, Fence Houses.
„ Seghill Colliery, Seghill, near Newcastle.
„ East Holywell Colliery.
„ Hetton Collieries, Fence Houses.
„ Whitworth Colliery, Ferry Hill.

Rules.

1.—That the Members of this Society shall consist of Ordinary Members, Life Members, and Honorary Members.

2.—That the Annual Subscription of each Ordinary Member shall be £2 2s. 0d., payable in advance, and that the same shall be considered as due and payable on the first Saturday of August in each year.

3.—That all persons who shall at one time make a Donation of £20 or upwards, shall be Life Members.

4.—Honorary Members shall be persons who shall have distinguished themselves by their literary or scientific attainments, or made important communications to the Society.

5.—That a General Meeting of the Society shall be held on the first Thursday or Saturday, alternately, of every Month (except in January and July), at twelve o'clock noon, or two o'clock, if on Saturday; and the General Meeting in the month of August shall be the Annual Meeting, at which a report of the proceedings, and an abstract of the accounts of the previous year, shall be presented by the Council. A Special Meeting of the Society may be called whenever the Council shall think fit, and also on a requisition to the Council signed by ten or more members.

6.—No alteration shall be made in any of the Laws, Rules, or Regulations of the Society, except at the Annual General Meeting, or at a Special Meeting; and the particulars of every alteration to be then proposed shall be announced at a previous General Meeting, and inserted in its minutes, and shall be exhibited in the Society's meeting-room fourteen days previously to such General Annual or Special Meeting.

7.—Every question which shall come before any Meeting of the Society shall be decided by the votes of the majority of the Ordinary and Life Members then present and voting.

8.—Persons desirous of being admitted into the Society as Ordinary or Life Members, shall be proposed by three Ordinary or Life Members,

or both, at a General Meeting. The proposition shall be in writing, and signed by the proposers, and shall state the name and residence of the individual proposed, whose election shall be ballotted for at the next following General Meeting, and during the interval notice of the proposition shall be exhibited in the Society's room. Every person proposed as an Honorary Member must be recommended by at least five Members of the Society, and elected by ballot at the General Meeting next succeeding. A majority of votes shall determine every election.

9.—The Officers of the Society shall consist of a President, four Vice-Presidents, and twelve Members who shall constitute a Council, for the direction and management of the affairs of the Society; and of a Treasurer and a Secretary; all of whom shall be elected at the Annual Meeting, and shall be re-eligible, with the exception of Three Councillors whose attendances have been fewest, and such Vice-Presidents as have held office for three consecutive years. All Officers to be elected from a List of Members nominated as eligible at the General Meeting before the Anniversary; which list will, with voting papers, be sent to every Member. All voting papers must be delivered personally at the Anniversary Meeting.

10.—The Funds of the Society shall be deposited in the hands of the Treasurer, and shall be disbursed by him according to the direction of the Council.

11.—The Council shall have power to decide on the propriety of communicating to the Society any papers which may be received, and they shall be at liberty, when they think it desirable to do so, to direct that any paper read before the Society shall be printed. Intimation, when practicable, shall be given at the close of each General Meeting of the subject of the paper or papers to be read, and of the questions for discussion at the next meeting, and notice thereof shall be affixed in the Society's room ten days previously. The reading of papers shall not be delayed beyond three o'clock, and if the election of members or other business should not be sooner despatched, the President may adjourn such business until after the discussion of the subject for the day.

12.—The Copyright of all papers communicated to and accepted by the Institute, becomes vested in the Institute; and such communications shall not be published for sale, or otherwise, without the permission of the Council.

13.—The transmission of the Proceedings shall be withheld from members more than two years in arrear of their annual subscriptions.

ERRATUM.

Page 190, 7 lines from bottom, dele line (See plate IV. for plan of extensive area of actual workings.)

NORTH OF ENGLAND INSTITUTE
OF
MINING ENGINEERS.

ANNUAL GENERAL MEETING, HELD AT BIRMINGHAM, IN THE BIRMINGHAM AND MIDLAND COUNTIES INSTITUTION, JULY 16TH, 17TH, & 18TH, 1861.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

THE annual general meeting of the Institute was held at Birmingham, on Tuesday, the 16th of July. The members and visitors from the different districts assembled at eleven o'clock, in the Hall of the Midland Institute. The President of the Institute (Mr. Nicholas Wood) occupied the chair. There were about 200 gentlemen present on the first day. The local arrangements were under the management of Mr. Carrington, assisted by Mr. Woodhouse.

The President took the chair precisely at eleven o'clock.

The PRESIDENT said :—Gentlemen,—I shall not at the present moment state to you the object which the Northern Institute of Mining Engineers has in view in meeting in the town of Birmingham, because I shall have to do so when I make my inaugural address, after the routine business of the Institute has been proceeded with. The first business which we have to transact is the election of new members. The usual mode of proceeding is, that the candidate shall be proposed by three members; that those names shall be suspended in the room of the Institute for a month; and then, that the election shall take place. In the present case, however, it has been determined to suspend the operation of that rule, and to proceed with the election at once.

The following new members were then elected, each being proposed by three members, in accordance with the rules :—Mr. Charles Edward Appleby, Derby; Mr. William Buxton, Staveley Colliery, Chesterfield;

Mr. Thomas Carrington, Jun., Derby; Mr. William Dunn Gainsford, Derby; Mr. John Jackson, Derby; Mr. Robert Heath, Newcastle-under-Lyne, Staffordshire; Mr. James Lindop, Bloxwich, Walsall, Staffordshire; Mr. John Brown, Cannock Chase, Staffordshire; Mr. Colin Napier, Westminster Colliery, Wrexham, Denbighshire; Mr. Henry Jackson, Astley and Bedford Collieries, Leigh, Manchester; Mr. Robert Aytoun, 3, Fetter Row, Edinburgh; Mr. Thomas Knowles, Ince Hall, Wigan, Lancashire; Mr. James Darlington, Chorley, Lancashire; Mr. Thomas Dunn, C.E., Winden Bridge Works, Manchester; Mr. Howard, Staveley Works, Chesterfield, Derbyshire; Mr. J. P. Hunt, Corngreaves, Birmingham, Warwickshire; Mr. William Bryham, Rose Bridge, Wigan, Lancashire; Mr. Thomas Livesey, Chamber Hall, Hollingwood, and Bradford Colliery, Manchester; Mr. Joseph Harris Smallman, King's Hill, Wednesbury; Mr. Richard Barrow, Ringswood Hall, Chesterfield, Derbyshire; Mr. Henry Dennis; Mr. Silas Bowkley; and Mr. Jacob Higmore.

Mr. WOODHOUSE explained to the meeting the arrangements which had been made with reference to the dinner, and excursion tickets to the members.

The PRESIDENT stated, that it was proposed that the reading and discussion of papers should commence on each of the first two days at eleven o'clock, and terminate as soon as convenient after four o'clock in the afternoon. The members would then proceed to visit the manufactories and other places of interest, which had been thrown open to them; and on the third day they would visit some of the neighbouring collieries and iron works, and afterwards visit the limestone caverns at Dudley Castle, which would be lighted up by the Earl of Dudley.

THE INAUGURAL ADDRESS.

By NICHOLAS WOOD, Esq., President.

Gentlemen,—It now becomes my duty to state to you the object of the Northern Institute of Mining Engineers in holding this meeting in Birmingham, their usual place of meeting being, as you are aware, in the town of Newcastle-upon-Tyne, in which the meetings have been hitherto held, which, I presume, I will best do by going into a few details—first of all as to the objects in view on the original establishment of the Institute; next, an outline of the labours of the Society since its formation; and lastly, I shall make a few observations on the step which has been taken in holding this the first district meeting of the Institute in Birmingham. In the first place, however, I beg to congratulate the members of the Institute upon the very great progress it has made since it was first established. At the first annual meeting of the Institute we had only about eighty members; at the present moment the number of members, including those gentlemen who have been proposed and elected to-day, amounts to very little short of 300—somewhere, I believe, between 290 and 300. (Hear, hear.) I will now, gentlemen, as shortly as I can, explain to you the object of the original formation of this Institute, and I think, probably, I shall best do so by reading a short extract from an inaugural address which I made at its first annual meeting, in September, 1852, the Institute not having then been established more than nine months. In explaining to the members of the Institute, on that occasion, the objects of its establishment I used these words:—"The object of this Institution is twofold, first by the union and concentration of professional experience, to endeavour, if possible, to devise measures which may tend to alleviate those dreadful calamities, which have so frequently conduced to the destruction of life and property, and which have always been attended with such miseries to the inhabitants of the district; and, secondly, to establish some kind of literary

association, the object of which should be to obtain some knowledge of the subjects of coal mining and other matters which are not contemplated in the ordinary literary associations which have hitherto been generally established." Now, gentlemen, after the experience we have had, I need not, I think, dilate upon the importance of the establishment of the present Association, because no person can doubt that it must be of very great advantage, if the labours of the Institution tend, in however slight a degree, to prevent the recurrence of those dreadful accidents which we too frequently experience; and if it was attended by no other result, I am sure you will be inclined to agree with me that, that alone would form an ample justification for the establishment of such an Institute. (Hear, hear.) Again, it seems very desirable that a literary institution, applicable to the coal mining interests of the kingdom, should be established for the purpose of endeavouring to improve the science and art of mining. Admitting, therefore, the necessity of the formation of such an association, I will next proceed to explain to you the progress that has been made by the Institute since its first establishment; and I shall do that best, perhaps, if I refer to the papers which have been read at our various meetings. As you are aware, this Institution has now been in existence rather more than eight years, and during that period we have had read about eighty papers, upon each of which there has been, of course, some discussion. I do not propose to trouble you, on the present occasion, by going into all the details of the discussions that have taken place; but I think I can shortly give you an outline, which will convey to your minds some notion of the character of the several papers which have been read, as well as of their practical value. I have taken out the list of these papers from the "Transactions" of the Association since its first commencement, and I have arranged that list under different heads, which, I think, will tend to bring out the various topics which have been brought under the attention of the members of the Institute. In the first place, I will endeavour to give you some account of the papers we have had laid before us, having reference to the *geological position of the different coal-fields;* and then I will go to those papers which relate to the *probable duration of the coal,* in a mining point of view. I propose next to pass on to the papers relating to the *analysis of coal,* and afterwards to those which have reference to the geological features of the different *ironstone measures,* and the various strata in connexion therewith. After that, I shall come to the *practical operation of mining*—first by *sinking shafts,*—next, *the working of the coal,*—then *the state of the*

gas in situ, and next the description of *power used for the purpose of ventilating the mines*. After that, I will proceed to explain those papers which have a general reference to the question of the *ventilation of mines in detail*; and then, I will endeavour to draw your attention to the subject of the different descriptions of *safety-lamps* which are used in mines. Next, I shall proceed to bring to your consideration the papers which have been read with reference to the *conveyance of coal underground*; and to several other matters which relate to the practical operation of the working of coal mines. These, gentlemen, are the heads of the different papers; or, at all events, of most of them, which have been read at the various meetings of the Institute, and which I propose to bring out in review before you. I think it necessary to go somewhat into detail, for the purpose of bringing clearly before you what we have done, and also to explain what we are doing; and I likewise feel, it is very desirable that there should be some reasons given why the gentlemen who are connected with our district, in the first place, and next, why the professional gentlemen connected with other districts where mining operations are carried on extensively, should combine together for the purpose of forming an institution of this kind. First of all, it is necessary for the purpose of obtaining that knowledge which is so important in mining operations; and next in imparting that knowledge to those who have not such opportunities, or who are yet in search of such knowledge. In the first place, it is very desirable that every person practically engaged in mining operations should know what has been done throughout the whole of the mining districts, and especially in those districts which have been the longest in operation, which are the most difficult to work, and where the most extensive working of mines exist; and, in the next place, it is also extremely desirable that they should know what has been left undone. And if the knowledge of what has been done, and what remains to be done, tends in any degree to promote the extension of the science of mining, I am quite sure that the members of the Institute, and others who are now met together, will agree with me that the time and labour which has been devoted by the Institution to the subject, have been very well and profitably bestowed. (Hear, hear.) I think, gentlemen, that we have a right to expect that more should have been done, in reference to the science of mining in the northern districts, than in most of the other parts of the kingdom. I hope you will excuse my putting the matter in that shape, because, whatever may be the state of mining operations in

other districts, it is quite clear that, if mining in Northumberland and Durham has not become more efficient than in some of the other mining districts which are of more modern growth, these northern districts must have fallen very far short of their duty. It is well known that mining operations in Northumberland and Durham were carried out to a very considerable extent, at a very early period indeed—long before any attempt to develope the mining capabilities of other parts of the kingdom. In the north the mining engineers were the first who had to contend with the great difficulty of mining in deep pits. They were the first who had to apply science and skill to the prevention of the danger arising from the presence and accumulation of large quantities of gas and water in the mines; and, therefore, of necessity they ought to know more of the science of mining than those districts which have more recently come into play; and which, up to a comparatively recent period, have not had these difficulties to contend with. It is, therefore, to be understood as no reflection upon other districts, if I put the mining of Northumberland and Durham so prominently before the meeting, because it is not too much to say, that those engaged in mining operations in these two counties, being the first who had to contend with all these difficulties, it is their duty to give the best possible practical information in their power to their neighbours who have not had so much experience, and who have yet to encounter these difficulties. And in this respect I may venture to express a hope, that the holding of the meeting of the Institute, on the present occasion, in the important town and neighhourhood of Birmingham may in these respects be productive of some practical utility. (Cheers.) At the same time, gentlemen, allow me to say that, notwithstanding our great experience in the north, we have still very much to learn—and that, too, in a great many phases, from those comparatively new districts with which we are constantly coming into contact — and which this meeting will, I trust, be the means of communicating. We shall hear the experience of miners from other districts, and we know that, in matters of detail, such knowledge can only be acquired by seeing mining operations in different localities practically performed, which we shall be enabled to do by the step we have taken in visiting this district. We know, for instance, that the coal in this district is very different from the coal in our district, and we know that those gentlemen who are engaged in the management of the mines of this district, have very much valuable information to communicate to

us, as to the mode of working their mines; which, in many instances, may be applicable to the working of some of the mines in our districts. Although, as I have said, the character of the coal is different, yet the practical operations of mining are in some degree similar to ours; and, therefore, I hope that it will meet with the approval of the profession in this district, that we have migrated, as it were, from Newcastle to Birmingham, with a view of interchanging the information and experience which we have each of us gained in our respective localities—(hear, hear)—and I cannot but think that such interchange of ideas must tend in the highest degree to our mutual benefit. (Cheers.) Reverting now to my original intention of explaining somewhat in detail the labours of the Institute, I should state that, with reference to the *geological character of the coal-fields*, we have had twelve papers read to us; and it is by no means surprising that the majority of these papers should refer to the coal-fields of Northumberland and Durham, and to the geological position of the coal deposits of these districts, rather than to those of other districts. It is well known that the geological position of the coal-field of the north is that of the ordinary or general position in which the coal-fields proper are generally found, *i.e.*, for the most part resting upon the mountain limestone, or carboniferous formation, and covered by the new red sandstone and magnesian limestone formations. There are, however, cases in which the coal of that coal-field is found resting upon, and overlaid by, other strata; and in these papers you will find a very full account of the general geological position of the whole of the coal-fields of Northumberland and Durham, and their relative position as regards the superior and inferior strata. We have recently had a paper (which was only communicated to the Institute at their meeting of last month), which is very important in its character:—a paper read by Mr. Boyd, which gives a description of a coal formation situated in the middle of the mountain limestone, comprising upwards of ninety feet of coal in the various beds. That is certainly a very unusual locality for a coal formation of such an extent, and I believe of rare occurrence in the regular carboniferous, or mountain limestone series. The paper to which I have referred, gives a very full description of these very extensive beds of coal, and also some basaltic dykes, and considerable slips or dislocations of the strata, and especially of the limestones of the mountain limestone series, and near the bottom of it—certainly below most of the limestones of that series in Northumberland. You are aware that in Scotland, the great coal beds of that country are associated with

limestone; but in that case the coal beds are near the top of the series. In this case the coal measures are most of them at the bottom of the mountain limestone, and very little above the old red sandstone; at all events, alternating with the sandstone that immediately overlies the old red sandstone. I think, therefore, you will find these papers very instructive as regards the geological position of these coals. We have not had many papers on the formation of other coal-fields; but we have one paper on the coal-fields of East Somersetshire by Mr. Greenwell, and one upon the coal-fields of North Somersetshire by Mr. Cossham. We have also had an account by Mr. Longridge of the coal-field in the Black Sea, which contributed, to a great extent, the supply of coal for the Crimean war. Still, looking to what has been done, it must be confessed that there is a considerable blank, as regards the geology of the different coal-fields, and that much still remains for this Institute to do. We certainly require a great deal more information than we yet have in respect to the coal-fields of different districts, for the purpose of comparison; and papers upon that subject, written with that view, will be extremely welcome to the Institute, and, I presume, very valuable to persons engaged in the management of mines generally. We have had one speculative paper upon the relative ages of the coal formations by Mr. Reid, and that paper you will find both very curious and instructive. It is, however, a difficult subject in these days to go into the question of the age of any formation, and more especially into that of coal, which seems to be distributed so very widely throughout the whole world. Then, gentlemen, we have papers on the *probable duration of the coal*, which are very important in their commercial character. I need scarcely mention to you the effect which the statements regarding the duration of coal have very recently had, upon the consideration by Parliament of the coal duties, and the question of the export of coal from this to foreign countries. On that occasion you will no doubt have remarked that there were very wide fluctuations in the different estimates made by different persons as to the probable duration of the coal-fields of England. Some gentlemen have put down that duration as extending from 1000 to 2000 or even to 3000 years. I do not know whether you would consider, that, supposing the existing coal-fields should endure for upwards of 2000 years, it is a matter of very great importance whether their duration extends much beyond that time, or to 1000 years more or less—(a laugh)—but the period during which the coal-fields of this country will continue to supply the demand is certainly estimated by some

gentlemen as low as 1000 years—while by others it is estimated at more than double that period. The question, however, is one of great importance, and it is also one upon which no certain or definite results can, at present, be stated with any degree of accuracy. Our experience has taught us that the deeper we penetrate the strata the more coal we find workable; and it seems that coal has been discovered, and is now worked at depths which at one time it was never thought practicable to obtain it, even in Northumberland and Durham. In both of these counties it was thought 600 yards was a very great depth at one time to mine for coals, but in these counties, and in some of the Midland counties, pits are sunk and coal worked much beyond that depth. If such be the fact at the present time, and the science of mining operations being progressive, it is impossible to prophesy what will be the result in time to come, inasmuch as we do not know what coal may exist below the present known seams. Altogether, therefore, this is a subject upon which gentlemen may well occupy their minds, and exercise a very great amount of ingenuity, in speculating upon the probable yield of this important mineral in the various parts of the country. We have also some papers upon the *analysis of coal*, but they have been chiefly confined to the coal in the Black Sea, for the purpose of comparing it with the coal of Durham. I think the question of analysis of coal is one of very considerable moment, and which deserves that the greatest attention should be paid to it, inasmuch as the distribution even of the chemical constituents of the coal exercises a very considerable influence in determining its commercial value. I have had occasion myself to report upon coal forwarded to me from two beds, one of which was considered to be the best gas coal in the district, and the other the best steam coal; one requiring that it should coke, and yield a large quantity of gas, the other that it should not coke at all, and yield no residue except white ashes; and I was surprised to find that the constituent parts of bitumen, carbon, and other ingredients existing in the two specimens, were almost precisely the same. The simple variation in the distribution of these elements, in the two specimens constituting the whole difference between what constituted commercially gas coal, and what steam coal; and therefore really a consideration of the analysis of coal is of great importance, not only to the managers of the mines, but also to those who are engaged in the commercial application of the mineral. I now come to the consideration of the papers on the *ironstone measures*, and of the *strata connected therewith*. In the first place, I may say, that this question forced

itself upon the attention of the Institute principally from the opening out of the Cleveland beds of ironstone, which has exercised such an important influence in the coal and iron trades of the county of Durham, and generally in other districts of the kingdom. We have had a paper on the Cleveland Ironstone by Mr. Marley, and every one who has read that gentleman's paper must acknowledge that he has treated the subject in such a manner as almost to exhaust it. It seems to me that, as an Institute we have a very ostensible and important duty to perform in ascertaining practically the characteristics and mineralogical features, as well as the geological formation, of the different descriptions of ironstone; and I am afraid in contrasting what we have done with what we have left undone, the comparison is much against us. In entering upon the consideration of the whole question of ironstone measures, and even in passing over the ordinary clay ironstones, which, notwithstanding their extensive distribution in different localities of the country, are yet well deserving investigation by the Institute, we have a very wide field of inquiry open to us:—We have in Scotland, as you are aware, the "Blackband," which is a very peculiar description of ironstone; and we have, in different parts of the country, the "Hematic" iron ore, which is comparatively a modern discovery of ironstone, and which is stated, in some parts of the county of Cumberland, to be of the most extraordinary thickness and yield; the bed being from forty to fifty feet thick of unmixed ironstone, yielding from sixty to seventy per cent. of iron; it has been discovered in South Wales as well as in Cumberland. Then there is a description of ironstone in the Cleveland district, which is "magnetic" in its character, and which yields a much larger per centage of iron than the ordinary ironstone of that district. Then, again, we have an ironstone which has been found in connection with veins of lead ore in the lead mine district of Durham, hundreds of tons of which were formerly thrown away as "rider" or refuse stone worked out of the old lead mines, but which, through the industry of Mr. Attwood, has been discovered to contain iron of exceedingly good quality, making some of the best iron and steel in the county; and there is likewise the ironsand formation. We have no account up to the present time of any of the several last-named ironstones in our "Transactions." I hope that gentlemen connected with the different localities, and with these ironstones, will give us the benefit, on some future occasion, of their experience, and favour us with some account of these several ironstones, and of their relative value. As an Institute, it is the description of information which we ought to have,

and certainly it cannot be said that without it, we are in any respect complete as an Institute. (Hear.) I will now shortly allude to a paper by Mr. Hurst, which excited a considerable degree of interest in our district, viz., a communication as to the *deposition of the different beds of sandstone, shale, and coal,* in one of the seams of coal in a certain locality in Northumberland. It is a paper containing various sections and plans, showing the different depositions of the various beds of stone, shale, and coal through very considerable depths of strata. I am sure that the study of this paper will be found to render considerable assistance in the study of a most intricate subject of investigation, viz.:—the relative ages and deposition of the various strata connected with the coal-beds and coal-fields generally, especially as in the details of the paper the remains of vegetable impressions, the types of the relative periods of these various deposits, and which are of great importance in the study of the formation of coal-beds in general, are there given. I am afraid I am dwelling rather too long upon the geological features of the coal and ironstone measures, and I will, therefore, now pass on to the operation of *sinking for coal.* Upon this subject we have a paper from Mr. Potter, which gives us an account of sinking through, in the county of Durham, probably the largest body of water that has ever been met with in the experience of any miner. I believe I am correct in stating, that in the particular mine referred to there were no less than 9306 gallons of water per minute, lifted from a quicksand, at a depth of ninety fathoms, or 540 feet; the horses power of the engines employed being 1584. This flood of water came out of a quicksand, about forty feet in thickness, which had to be sunk through; and the difficulty of sinking through a quicksand forty feet in thickness, with a feeder of water of 9300 gallons a minute, it must be confessed was no light matter. (Hear, hear.) However, whatever the difficulty was, it was overcome by Mr. Potter, but not without great exertions and great scientific skill, and the colliery has for some years been in full working operation. I feel assured that the study of that paper will well repay the perusal by all practical miners. Then you have an account of sinking through the same strata, and about the same thickness of quicksand, by myself, at a colliery not more than a couple of miles from the locality sunk through by Mr. Potter, the quicksand extending no doubt from the one pit to the other. In this case it was sunk through without a separate pumping engine, the mode adopted being that of insulating, by metal tubbing, each separate feeder of water, as they were successively met with, in each stratum of sand and limestone;

so that though an aggregate amount of upwards of 5000 gallons of water was met with in sinking through the bed or beds of sand and limestone, so successfully was this accomplished, that we never had more than about 500 gallons in a minute at one time to contend against, and which was lifted by the ordinary winding engine of the colliery. I cannot, of course, go into the details of the respective operations in an address like the present. I mention the cases to direct your attention to the two operations. In the one case the feeder was 9300 gallons a minute, the whole of which was encountered at one time, and had to be lifted, by ten engines and machines, from the sand; and in the other, whilst passing through the same quicksand, by detaching the feeders of water, and so having only 500 gallons to encounter at one time in passing through the quicksand, the engine power employed in the one case was upwards of 1584 horses power, whilst in the other it was only about 250 horses power. These papers are well worthy the consideration of the members of the Institute, as showing the nature of the feeders of water which are met with in sinking through the magnesian limestone and sand, in the county of Durham, and the different modes of sinking through them. We are promised an account of another sinking in the same neighbourhood by Mr. Taylor, in which the operation of sinking through the limestone and sand was performed in a somewhat different manner, which will, I doubt not, be an equally interesting paper. I think these papers will be found to be extremely interesting, as any facts brought forward with reference to the subject of sinking through quicksands and limestone at great depths, must be useful in other districts; and are, therefore, in that respect well worth the consideration of the members of the Institute. (Hear, hear.) The next paper to which I beg to allude is on the subject of *cutting coal by machinery*. We have only had one paper on that subject. It seems to be a very difficult operation. I very well recollect Mr. Stephenson, in the early part of his life, being quite convinced that there would be no difficulty whatever in cutting coal by machinery. Mr. Stephenson, however, tried his hand at it, and although perhaps no one was more capable of devising means for effecting such an object, he was obliged to give it up, and the result has been that up to this time we have not been able to cut coal by machinery. The subject is a very important one, and has been much considered, and no doubt will be further considered by the members of the Institute. Then we come to a very important question, namely, the question of the *best mode of working coal*; and, as may be expected, the papers presented to us have been principally

with reference to the working of coal in the counties of Durham and Northumberland. You are aware that there has not been much experience in the working of coal by long-wall in these two counties, and consequently we have had very few papers upon that subject. We have had, however, a paper from Mr. George Elliot on the subject of the working of one seam of coal above another; and also a paper by Mr. Barkus on the same subject. With reference to the working of coal by the long-wall system, we have, as I have remarked, little or no information at all, and therefore I hope the information which we shall receive at the present meeting, will be such as to enable us to grapple with such an important desideratum. I am most happy to find by reference to the minutes of papers to be read, that there will be a paper contributed on this subject by a gentleman who is connected with the locality in which such a mode of working is extensively prosecuted, and who has great practical experience on the subject. I allude to my friend Mr. Woodhouse—(cheers)—I have no doubt that his paper will prove most interesting, and will give us that information which we more particularly require in the north of England; and I hope, likewise, that the discussion, which in all probability will take place after the reading of this paper, will be such as to present us with the views of all those gentlemen who are practically acquainted with the subject, and who may happen to be present at this meeting. (Hear, hear.) The next class of subjects deserving of inquiry is that which relates to the peculiar state and escape of *gas, in situ*, from the beds of coal at different depths from the surface. On that subject we have had four papers, the principal of which was contributed by the late Mr. Taylor. The papers on this subject are very interesting, and have elicited some very curious facts. The depths to which the coal has been worked in the northern districts, and which develope to its full extent the phenomena that accompany the evolution of gas, *in situ*, at different depths from the surface; and the great quantities of gas yielded by that coal has, of course, presented many opportunities for the consideration of this subject. It is a very curious fact, as respects the northern coal-field, which is shaped like a basin, deep in the centre, and rising in almost every direction around that centre, that in the extreme depth of the basin there is comparatively no gas at all. I am working two collieries within a short distance of each other, and in point of fact, working into each other. One of them is from 240 to 250 fathoms deep, and the other about half the depth, say 120. It is a very curious fact, that in the deepest of these two collieries there is very little gas in the

deep workings; whilst in the other, which is not half so deep, there is a large quantity of gas, probably the greatest quantity which exists in any colliery in the district. I can only account for it on the supposition that in the extreme deep part of the basin or workings, as the lighter carburetted hydrogen gas oozes out of the fissures of the coal, it is replaced by the heavier carbonic acid gas, and that such light carburetted hydrogen gas then ascends towards the more elevated parts of the mine, and being there unable, from the nature of the strata, to find its way to the surface, is found in excess. We have, therefore, a zone, as it were, at or around the bottom of the basin of the mine, comparatively free from the existence of light carburetted hydrogen gas, and a zone where such gas, not being able to find its way to the surface, is in excess; and that these are almost always followed by another zone where the gas does find its way to the surface, and which is consequently comparatively free from inflammable gas, the quantity depending upon the facility with which such gas can find its way to the surface. Whether that be a correct explanation or not, the subject is a very interesting one, and it is hoped that when the attention of the members of this Institute is thoroughly directed to it, we may have more facts brought before us; which, derived from different localities, may fully elucidate the subject, and direct us in our operations of dealing with this extremely subtle and dangerous gas. Then, following up the routine of papers, we have, the consideration of the question of the *proper situation of the upcast and the downcast shafts;* whether it is best for the ventilation of the mine, and for other purposes, that the upcast shaft shall be at the rise, or at the dip, of the coal-field to be worked? On that subject we have a paper by Mr. Longridge, and we have some observations upon the same point, in an able paper contributed by Mr. Atkinson, with reference to that subject and to the evolution of gas generally. It is a very important subject, and has occupied the attention of gentlemen connected with different districts for a very long time. Still we want more facts upon this intricate subject, before we shall be able to arrive at any satisfactory conclusion upon so important a question, and I hope, therefore, that one result of the present meeting will be to elicit the production of such facts; or, at all events, by directing the attention of scientific gentlemen more particularly to the subject than has hitherto been done, we may, at the future meetings of the Institute, obtain such information, so valuable to all practical miners, that may set the question at rest. (Hear, hear, hear.) With reference to the very impor-

tant subject of the description of *power for producing mine ventilation*, we have papers by Mr. Longridge upon the relative advantages of the steam-jet and furnace as mechanical powers of producing ventilation. With reference to the steam-jet and the furnace, the latter being the general mode of producing ventilation in the Durham and Northumberland coal district, we have several papers by myself and others; and Mr. Atkinson, one of Her Majesty's Inspectors of Coal Mines for Durham, has given us, from time to time, some extremely important information upon the theory of ventilation generally. But upon the *production of ventilating power*, other than by the furnace or steam-jet, and by means of machinery we have only had one paper. Neither do I think that we have anything like exhausted the question as to the best description of furnace power for the purpose of ventilating mines. We have only recently had our attention called to this point more particularly by a paper from Mr. Daglish. There is very considerable variation in the mode of building furnaces at the different collieries, and there is still, I think, much information required as to the best mode of creating ventilating power by furnaces. I hope, therefore, that as the subject generally has now been brought prominently before you, you will be able to collect such information upon the subject, as may enable you to arrive at such a conclusion as will lead to the adoption of the best and most efficacious system of ventilation—a conclusion which is of paramount importance, not only to the colliery owner, but to the men who are engaged in the actual operations of mining. We must endeavour, therefore, to collect, and reduce into a system, all the information we can obtain with reference to the description of mechanical power most efficient in producing ventilation. We are promised a paper by Mr. Blackwell upon that subject at the present meeting, and I trust that we may be favoured with the presence of that gentleman at this meeting, and that he will give us the result of his experience on this interesting and important subject. (Hear, hear.) I need not point out to you, who are men of practical experience, how very desirable it is that in such an Institute as this, we should have every subject connected with the working and ventilation of mines, as fully discussed and developed as possible; and certainly the production of a power for ventilation, whether mechanical or otherwise, is all-important. We know that in some districts of South Wales, and in the Midland districts, mechanical power for purposes of ventilation is used very successfully. We must admit the deficiency under which we labour in the North of England, in conse-

quence of want of practical information upon the subject; and, therefore, I hope that we shall have papers upon the subject from gentlemen who have acquired practical experience in the matter. (Cheers.) Then we come to the general subject of the *ventilation of mines*, and upon that subject we have in the papers already printed some very important information. Altogether, I think we have about a dozen papers on the ventilation of mines. We have had one, which I mentioned a few minutes ago, on the theory of ventilation, by Mr. Atkinson; and we have had some others by that gentleman, and by our late lamented Vice-President, Mr. Thomas J. Taylor; and I am convinced that every one who has read these papers will admit that they exhibit extreme diligence and industry in the collection of facts, and great scientific skill in their practical application to the purposes of ventilation. It is not only the theory of ventilation, but the practical application of those theoretical disquisitions which render these papers so valuable, and which the practical experience of these gentlemen enabled them so fully and clearly to explain. I must say that, in my opinion, there is such a mass of information already collected upon this subject, in the existing volumes of the Institute, that will go far towards laying the foundation of a system of ventilation in coal mines, as near approaching perfection as anything connected with such a subject can attain. I may take the liberty of mentioning to you two cases, which show the extreme importance of arriving at some definite and settled conclusion as to the theory of ventilation. Recently, as you are aware, there have been two very serious and lamentable accidents in this country—one at Hetton, in the county of Durham; and the other at Risca, in South Wales. A great deal of attention has been paid at Hetton Colliery to the ventilating power of furnaces, and Risca Colliery is ventilated by one of Mr. Struve's machines. At Hetton, the distribution of air around the workings of that colliery, which are most extensive, is accomplished by a water gauge of only an inch and a half; and it is found that a water gauge of that amount is a very adequate power, and amply sufficient. We get by it from 200,000 to 300,000 cubic feet of air per minute distributed through a mine with several miles of air passages. At Risca Colliery, according to the evidence at the inquest, they had a ventilating power to the extent of four and a half inches water gauge, and the quantity of air distributed through the mine by the operation of that gauge was only about 60,000 cubic feet of air per minute. Now, seeing the difference which existed between the power exhibited by the two gauges, one is apt to imagine that there

is something wrong in practice, with respect to one or the other of them; and as the subject of ventilation is so very important, I think it ought to be very closely investigated, which is wrong, and which is right, in practice. I do not mean to say that the mechanical power which was used at Risca, of creating ventilating power, was an improper mode, or that it was even deficient in power; it seemed to do a vast deal of duty; but it is perfectly clear that it leaves the question open, as to whether a water gauge of four inches and a half, or one of one inch and a half, is the correct one to adopt, or to use as the practical ventilating system of a colliery. I think, therefore, we still either want more information, or a more decided understanding, founded on what is already known, on the subject of the production and distribution of air in coal mines for the purposes of ventilation, and, consequently, as to that mode which will produce the best practical result. I believe that we are universally of opinion that the only safe mode of dealing with inflammable gas, is by means of dilution by ventilation, so as to prevent its accumulating in any particular portion of the mine to the inflammable point; and if that is so, it is extremely desirable, that we should be all of the same opinion, as to the best means of producing the requisite ventilating power, and likewise the best mode of distribution, or that mode which tends to disseminate the air throughout every portion of the mine in the best and most efficacious manner. I believe you will find the whole theory and practice of ventilation gone minutely into in the papers to which I have alluded; and I think the subject well worthy of your consideration and investigation. As professional men, dealing with the evolution of gas in coal mines, and endeavouring to produce results which will have the effect of controlling that gas, and averting those calamitous accidents which yet too frequently occur, it is incumbent upon us to pursue this subject, up to a point at which we shall arrive at some sound conclusion, as to the best and most efficient mode of accomplishing these objects. I do, therefore, hope that gentlemen connected with practical mining operations, will carefully note and record all the circumstances which attend the evolution of gas, and the mode of dealing with it, in their different districts; and that we shall have additional papers presented to the Institute, upon the different systems of ventilation, and more especially upon that branch of it which has reference to the ventilating power which is produced by machinery, and likewise the different modes in use in the distribution of the air. (Hear, hear.) Then we come to the subject of *cages*, which is a very important

one; and, being so, it is rather surprising, that upon that question we have only had one paper, and this is the more extraordinary, as, I believe, almost every colliery has a different description of cage; and I do not know that we have come to any satisfactory conclusion, as yet, as to the best description of cage to be used in coal mines. I think upon that point you will have a paper read to you to-day by Mr. Aytoun, and you will have an opportunity of discussing the question when it comes before you, after the reading of that paper. There is another subject to which I am desirous of directing the attention of the members of the Institute, and that is with reference to the different kinds of *safety-lamps* which are used in the various districts. No one can doubt, considering how much the successful working of a coal mine depends upon its freedom from accidents, and particularly from accidents caused by the explosion of gas, that this is a subject of extreme importance. We have had a variety of good safety-lamps, but I do not know that we have as yet had what may be termed a perfect safety-lamp. In the early period of my life, many years ago, and at the first introduction of safety-lamps, I gave this subject great attention; and I also had great experience in dealing with gas previously to the introduction of safety-lamps. Any remarks, however, as to the mode of dealing with gas previously to the introduction of safety-lamps, in the present age, must necessarily be out of date, and could not convey much instruction to the present meeting. But at the commencement of the system of working mines by means of the safety-lamp, Mr. Stephenson and I made a very minute investigation, and made innumerable experiments, into the nature and properties of the explosive gas in mines, and on the principle and comparative safety of different lamps. Numerous experiments have since been made by other gentlemen. The whole of these experiments and investigations seem, however, to have resulted in the adoption of two descriptions of safety-lamps, namely, those invented by Mr. Stephenson, and those by Sir Humphrey Davy (with the modifications by Dr. Clanny and others). They are somewhat different in the mode of construction, but the principle of safety is the same in all of them; namely, that the explosive gas in mines does not pass, whilst in a state of ignition, through apertures below a certain size. In the counties of Northumberland and Durham, the Stephenson, the Davy, and the Clanny lamps are generally used; and I believe that, in almost every case, they are considered to be equally safe. I have myself always considered (but that may be the

result of early associations) that the Stephenson safety-lamp is superior to the Davy, or Clanny. I have always considered, that the glass shade which covers the wire gauze in the Stephenson improved lamp, and which, though it does not enter into the principle of safety (the safety depending upon the apertures of the wire gauze), acts as a protection to the gauze, and prevents it from getting smoky or injured; and I likewise consider, that the glass shade restricting the admission of air into the interior of the lamp, and thus diminishing the intensity of combustion, and preventing the wire from becoming red hot, as in the case of the Davy-lamp, is an additional security; and where there is a strong current of air, the Stephenson-lamp is also preferable, as the flame cannot be made to pass the apertures of the gauze. In the Clanny-lamp, the safety depends upon the glass remaining perfect; whereas in the Stephenson-lamp, if the glass is broken, the wire gauze around it becomes the principle of safety, as in the Davy-lamp—it becoming then, in fact, a Davy-lamp. However, I do not mention these comparisons to throw doubt or discredit in any degree upon the safety of the Davy or Clanny lamps; because, as I have already stated, the safety of these particular descriptions of lamps is well established. (Hear, hear.) You will find, in the "Transactions" of the Institute, a record of a great many experiments which have been made from time to time, in order to prove the safety of lamps of every description. The results of these experiments go to show, that a well made gauze lamp is quite safe in all ordinary cases. If you refer to the experiments which I have made upon this subject, and which are given in the proceedings of the Institute, (and I mention this because I have recently seen, in some of the scientific journals, a discussion in which the safety of the lamps is questioned), you will see that, when the gauze becomes red hot by the ignition of the gas within it, and when in that state it is subjected to a strong current of air, the flame of the lamp is apt to pass through the gauze; but this is in extraordinary cases, and cases which can scarcely, if ever, exist in a mine, namely, a strong current of air in an explosive atmosphere. This is, however, a portion of the subject which I think requires further investigation, and which I hope it will receive at the hands of the members of the Institute. Then we have had some papers on the *Accident at Lundhill Colliery*, and also on the *Explosion at Burradon Colliery*. I think, if all the facts which attended these great explosions were collected together, and subjected to investigation, they would be extremely useful in preventing such accidents in future.

(Hear, hear.) I have no doubt that, if we pursue this subject more than we have hitherto done, some beneficial results will follow from our investigations. Then we come to the question of the *conveyance of coals underground.* That is a most important subject, in a commercial point of view, and it is one which, I think, has hardly received that attention from mining engineers which it most certainly deserves. I am glad to find that we shall have a paper read upon that subject at the present meeting, which will bring it fully before the members of the Institute, when, I have no doubt whatever, it will be properly discussed. You will find, in the proceedings of the Institute, two papers by myself upon this subject, which, I believe, are the only papers we have had at present; and I hope you will find them useful, and that they will aid you in the consideration of this most important question. I have come to the conclusion that (with a few exceptional cases) there is no occasion to have a single horse underground; and I have pointed out the way in which the underground conveyance of coals may be effected without the use of horse power. I know that there are pits in the North of England, where there are no horses employed at all, and as the question involves the economy of working the mine, and is so important in a commercial point of view, it ought to be attentively considered by every professional man. I am very glad that upon the present occasion we shall have it brought regularly before us, by a paper devoted to this special purpose. (Hear, hear.) There are some papers upon *wire ropes* and upon subjects connected with them, and we also have papers upon *boiler explosions.* One of these explosions, as you are aware, occurred recently at the Hetton Colliery. It was a most extraordinary explosion, and certainly involves questions which go a great deal further than what arises out of a simple boiler explosion. This was the case of an explosion in the flue, and not of the boiler itself, of an engine underground. The engine and boiler had been in use, and indeed in actual working thirty-four years. There had been no variation of the circumstances in reference to the boiler, the mode in which it was set, the arrangement of the flues—there was no variation whatever in the fireplace, flues, boiler, or machinery; it was at the time of the explosion in precisely the same state as when it was erected thirty-four years ago, and as it had been in use day after day during that period. All that time the engine worked without the slightest interruption, and then an explosion of gas in the flues takes place, which might, in all human probability, have taken place on

any day during the thirty-four years. This clearly shows that the explosion arose from peculiar circumstances, which might have occurred, or which may occur, at any time with any boilers under similar circumstances, and there are many such underground at the present time. It is supposed that there had been a production of gas, from the coal thrown upon the fire to damp it, similar to that which is produced in a retort at a gas work, and that that gas had accumulated, to a certain extent, in the flues, and that it had, in some manner or other, been set on fire or exploded; but in what manner this had occurred was quite a mystery, as there was no fire except the boiler fire, and the air passing through the fire doors and damper passed into the flue where the explosion took place, direct from the downcast shaft. There could not have been more than 3000 cubic feet of gas in the flue, supposing it to have been entirely filled with gas, and such was the force of the explosion that it blew up a crossing at a distance of one and a quarter mile from the seat of the explosion, and some men were killed at a distance of six hundred yards, by the simple concussion of the explosion. The whole question was fully gone into at the Coroner's inquest, but it presents a very serious aspect in this respect, that if the conveyance of coal underground, depends upon the boilers of the engines being placed down the pit, and if the flues of these boilers which are put down the pit are liable, upon certain conditions, to an explosion at any time; it becomes a serious matter for consideration, as to whether you should get the steam from boilers placed down the pit, or that the boilers should be placed on the surface, and the steam conveyed down the pit, and, consequently, not subjected to the danger of explosions of this nature. You will find, by reference to the "Transactions" of the Institute, that the question of the conveyance of coal underground has been fully discussed, and that there have been a great many experiments made as to the comparative merits of placing boilers underground, and of placing them aboveground. The accident at Hetton cost fully £10,000, besides attendant expenses, and, therefore, it is extremely desirable that the question, as to whether it would be best to have the boilers at bank and to take the steam down the shaft, or to have the boiler underground, should be fully investigated. We have also had some papers with reference to the best mode of freeing the mine from water, a subject which, for some time, has attracted the attention of the Institute. And then we come to the subject of *barriers in mines*, that is, as to the practical utility of leaving barriers of coal

between each colliery, to insulate one from the other; and whether, in fact, such barriers are practically operative in preventing the water from flowing from one colliery to the other. The fact is, that in Northumberland and Durham there is an area of several thousand acres of underground workings, in which the coal has been worked, and although it had been the practice to leave what was supposed to be adequate barriers between each colliery, the practical result has been, that from Shields to Newcastle, a distance of ten miles, and for a space of some five or six miles in width, these barriers have been found to be of no practical utility, and that the water of the different collieries has found its way from one to the other, and has formed a vast lake of that extent. If, therefore, it is found in practice, that the system of leaving barriers between collieries is ineffective, observe what an immense loss of coal is occasioned thereby. This certainly is a question which, especially as regards the north of England, may most usefully and beneficially occupy the attention of the Institute. I think the only other matter to which it is necessary for me to direct your attention, is a paper which has been brought before the Institute by Mr. Beanland, and refers to the mode of taking more accurate *surveys of collieries underground*, and I mention it more particularly on account of its novelty. You know that the system upon which the underground surveys are made at present is by the magnetic needle, which can never be much depended upon, principally from the great number of tramroads underground; and yet, at the same time, it is of very great importance that accurate surveys should be made. Mr. Beanland's plan is to obtain a base line from the transit of a star across the mouth of the pit, and then work out the survey underground from that line by the theodolite; applying, of course, a similar base line to the survey of the boundary on the surface. I mention it incidentally as a novel mode of surveying underground workings, and I know that some surveys which have been made in that manner have been remarkably accurate. I cannot close my remarks on this occasion without expressing the deep regret which we, in common with all classes of society, and particularly the members of the Institute, have felt from the removal by death of three of our Vice-Presidents, within a very short period of each other—Mr. R. Stephenson, Mr. Locke, and Mr. Taylor. Two of these lamented gentlemen were members from the earliest formation of the Institute; and although Mr. Locke was not so early a member, he was of great assistance to us on all occasions, especially in Parliament. It is fitting, then, that we should place upon

our minutes the expression of our deep regret at the loss of such eminent men, as a tribute of respect to their memory, on this the first district meeting after that sad event. Gentlemen, I have now, although very ineffectively, I fear, given you an outline of the objects of the Institute when first formed, and what has been done since its formation. I hope we have fulfilled our mission. (Cheers.) We have performed, to the best of our ability, that which we set out for ourselves to accomplish; and if we have not done all that we ought to have done, it has arisen from want of ability, or want of time, and not from want of intention or exertion on our parts. (Hear, hear.) I have stated to you what has been done up to this meeting, and, in a general way, what yet requires to be done; and I hope it will have the effect of stirring us up to make still greater exertions, in order to clear up points upon which doubts and differences of opinion still exist. (Cheers.) I am rejoiced to see so large a meeting in this room on this occasion. (Cheers.) It shows the interest which the mining community, and the trade generally, take in the Institute, and I do anticipate that the most beneficial results will flow from such a meeting. We are greatly indebted to the gentlemen of Birmingham for their kindness in affording us the accommodation which we have obtained; and I can only say that we feel deeply grateful to them, likewise, for the very friendly manner in which they have received us, on this our first visit, which I most sincerely hope and trust will be beneficial to us all. I will now, gentlemen, detain you no longer, but beg to call on Mr. Bailey to read the first paper. (The President resumed his seat amidst the cheers of the meeting.)

ON THE

ADVANTAGE AND NECESSITY OF THE INTRODUCTION OF

STEAM POWER

FOR THE PURPOSE OF

UNDERGROUND CONVEYANCE

IN THE

COAL AND IRONSTONE MINES OF SOUTH STAFFORDSHIRE.

By SAMUEL BAILEY, Walsall.

The present state of the coal and iron trade is a cause of much anxiety to every coal and iron master in every district throughout the United Kingdom. Every person who is in any way connected with this branch of trade is complaining of so little being done—no orders—or if any orders, at little or no profit being realized upon articles manufactured or materials raised. Every newspaper gives a deplorable account of trade in general, and if any one district be more referred to than another, it is South Staffordshire, which was once the light and life of the iron trade; and we frequently hear it said, that South Staffordshire has had its day: it cannot again compete with other districts where coal and ironstone are in greater abundance, and are being raised cheaper. Not that it is said that the coal and ironstone of South Staffordshire are inferior, or that the iron produced is inferior to that manufactured in other districts, but the reverse; the quality cannot be surpassed. No, the complaint universally made is, that the coal and ironstone are too expensive and cost too much in getting; that the charters are too much, the royalty is too high, the dead charges are too great per ton on the small quantity raised, and that nearly two tons ought to be raised for the sum which one ton now costs.

And a reduction to something like this extent in the cost of raising

these minerals must be made, otherwise most of the large and extensive works which have been established in this country, at such a great outlay, and some of which have been arranged upon the most improved principle, must come to a stand.

Indeed we hear, from a statement made by Mr. S. H. Blackwell, of Dudley, a high authority, and published in the *Midland Counties Herald* of June last:—

"That there are upwards of twenty mills and forges now standing in South Staffordshire, which in all probability will never again go to work, and that the suspension of these works has not arisen in every case from want of capital or reckless trading, but from the utter inability of obtaining cheap supplies of minerals.

"That in some very important cases royalties on ironstone in South Staffordshire are higher than the entire cost of iron ore in other districts, and that the rate of wages is much higher also.

"That these circumstances are acting powerfully against this district, and the men are leaving it for places where they can obtain regular work, even at lower rates, and that certain branches of the manufacture hitherto almost entirely confined to South Staffordshire, are being taken to districts where the cost of carriage is 15s. to 17s. 6d. in favour of the makers, and this in cases of finished iron, which the South Staffordshire ironmasters have hitherto refused to believe could be made elsewhere."

Mr. Blackwell continues, in reference to the prospects of the iron trade in this locality:—

"I should regret if, from the remarks I have made, it should be inferred that I regard the continuance of the trade in this district as impossible. If all parties interested in it would accept the change of circumstances, South Staffordshire may for a long time yet be an important iron-making district.

"Its great local trade, its central position, its power of bringing supplies of ores and pigs from other points, and the superior quality of its marked brands, place this quite within its reach; but to insure this, all parties must accept the change of circumstances.

"Landlords must not expect 2s. 6d. per ton royalty on ironstone, which costs from 8s. to 10s. per ton more to raise. Ironmasters generally, instead of ignoring the advantages of other districts, must wisely avail themselves of these advantages for their own assistance, and they certainly must not blind themselves to the progress which the manufacture of iron has made during the last twenty-five years.

"On these conditions, South Staffordshire may still, for years to come, remain an important iron-making district, although it may never again obtain the prominent position which it once had."

Here, then, is a statement of facts, in plain English, which cannot be disputed, and which tells us that we are not able, in our present state, to compete with other districts, or even exist as an iron-making community.

It is time, therefore, for us to consider what steps can be taken, and measures adopted, to reinstate ourselves in the position we ought to occupy in the trade.

So far as minerals are concerned, the only drawback we have, in comparison with other districts, is in the supply of the article of ironstone, and the cost of getting it. Coal we have in abundance, and of a quality suitable above all others for making iron.

That golden measure, the "thick coal," is not yet exhausted, as we learn from a very interesting and valuable paper read before the Institute of Mechanical Engineers, in August last, by Mr. Wm. Matthews. But in the matter of our ironstone, while we have no complaint to make as to its quality, it is well known that in point of produce it is much below that of ironstone measures elsewhere, and consequently the cost of raising it must be considerably greater.

The question, then, as it appears to me, which it becomes us to consider is, *the practicability of reducing the present cost of raising our coal and ironstone.*

The ironworks, mills, and forges are undergoing improvements every day; endeavours are being made to economise fuel and labour; still all these improvements do not make the difference required, the cost of obtaining minerals being too great. The coal and ironmasters say, "We cannot raise coal and ironstone cheaper than we are doing; we have done all in our power; we have reduced the colliers' wages and other expenses as low as possible." Now, this is true, the masters cannot do more; it is not, therefore, with them the matter rests; the parties with whom the duty rests of reducing the cost of getting coal and ironstone in South Staffordshire are the mine agents; it is for them to bestir themselves, to lay aside the old methods of their forefathers, to improve and re-arrange their pits, workings, and machinery, and economise the labour of men and horses, aboveground, and more especially underground; and with this general reduction of labour, must at the same time be combined a large increase in the quantity raised, so as to reduce the current

expenses upon the quantity so raised. Thus shall we be able not only to sell coal in this district, cheaper than it is now being delivered here from other distant districts, but at such a cost as will enable us to compete with such districts in other markets.

To effect this change, it is of the utmost importance that meetings should be established, for the purpose of discussing the merits of different methods and plans which must be employed for the purpose of carrying out the object in view. Such meetings would result in great benefit to proprietors, workmen, and agents alike, and I cannot but think that the establishment of them would receive the support of the principal coal and iron masters of South Staffordshire.

To return, however, to the subject of my paper, from which, I trust, I have not altogether digressed. One of the points most demanding our attention, with a view to the reduction of the cost of raising coal and ironstone in this district, is the underground conveyance from the face of work to the pit shaft. By our present imperfect and expensive mode of conveyance, we are in many instances prevented working our pits so extensively as we otherwise should.

By the time the face of work is two or three hundred yards from the shaft, the expenses of conveyance are so great upon the ton raised, that it actually becomes cheaper to make a new plant, and sink new shafts, even when the old plant is best situated for the transmission of the minerals to the works, canal, or railway; by which additional plants more surface land is destroyed, and new tramways are required to be laid down.

It is often said that coal can be delivered 6d. per ton cheaper above-ground than below in this district, which is indeed a fact, under present circumstances. Besides, we are prevented having more extensive pits, in many cases where the roof is tender, and it is therefore necessary to work the measures quickly; the face of work is limited to one or two hundred yards in length, whereas, by an improved mode of conveyance, measures with tender roofs may be worked more extensively, because more quickly, and so to much greater advantage.

The present mode of conveyance underground in this district is much the same as it has been during the last two or three generations, with the exception of the introduction, during the last twenty years, of wheel skips working upon tram-rails, instead of the old "slipe" or "sledge" skip, which is even now used in some instances.

This latter method is still so much adhered to by some of the old colliers,

that I was asked some time ago to allow the wheel skips and rails to be taken out, and the old slipe skip again introduced.

But however well these methods have served their purpose in times past, the day is now come when they no longer meet our requirements.

When the South Staffordshire iron trade could afford to give 10s. or 12s. per ton for coal, and 20s. and 24s. per ton for ironstone, there was not the necessity felt as now for such improvements in working our minerals, seeing that great profits were realized with which proprietors were satisfied. But now, in consequence of railway communication, when we have all the world to compete with, and when coal is delivered in this district from north, east, south, and west, and at nearly the same prices we are paying for getting, it is indeed time for us to bestir ourselves, if we are to exist and compete with other districts; and we must not only be able and prepared, as before stated, to raise minerals in this district cheaper than they are being delivered from other localities, but we must in some cases compete with them in other markets. To do this, there are several things demanding our attention, viz., our winding machinery to be improved, more extensive underground workings to be opened, skips, wagons, and tram-roads to be better constructed, so that instead of raising seven or ten skips an hour, thirty or forty may be drawn, and instead of sixty tons per day, 250 or 300 tons must be raised, for it is quantity also that must answer the purpose intended of reducing the cost per ton.

We will suppose an area of fifty acres of coal to be worked, four feet six inches thick, producing in round numbers 200,000 tons. This, with the present usual mode of working, would require from first to last, two, three, or four plants, a quantity not exceeding 300 tons per week could be raised, and a period of thirteen years or thereabouts would be required to work it out. The cost of making these plants would be, say £5000, or 6d. per ton upon the whole quantity to be raised: additional charges in charter, royalty, and other expenses, would make the total cost of raising about 6s. per ton. So great must be the current expenses upon the small quantity raised, hence the lessee would be thirteen years before receiving back his outlay, and whatever return the measure might realize in the way of interest, profit, &c. If, however, instead of the present mode of working the seam, one good plant were made at once, even at a cost of £5000, if the pit were driven out more extensively, if the speed of the winding engine were increased, and instead of employing ten or fifteen horses and drivers to raise 300 or 400 tons per week, an engine were put down, which, with the assistance of five or six horses, would

raise 1000 or 1500 tons per week, then the common charges, instead of being 1s. or 1s. 6d. per ton, would be reduced to 6d., and even in some cases to 3d., and the seam of coal worked out in one-third of the usual period; and by means of this increase in the quantity raised, not only would the current working expenses be reduced, but the lessees, though receiving perhaps a less profit per ton, would still be obtaining a larger income from the extra quantity raised within such a brief period; and the lessor could afford to reduce his royalty, since he would receive it on the whole area of the seam leased, in about one-third of the period he otherwise would.

Seeing, then, that by the introduction of steam power into our pits for the purpose of underground conveyance, the cost of raising minerals would be so greatly reduced, while allowing a fair royalty to the lessor, as well as a fair return and profit to the lessee, it is evident that in this way and by these means the condition and prospects of the iron trade may be greatly improved, so far, *i.e.*, as a reduction in the price of minerals is necessary. In introducing this proposition to the meeting to-day, from a conviction that if generally adopted it would materially assist in preventing that total relapse in the coal and iron trade of this district with which (as Mr. Blackwell asserts) we are now threatened, I can truly say how much I wish it had fallen into other and abler hands to have brought it before your notice.

My object in bringing it before this meeting is to elicit information, more especially from those gentlemen present who, from their great experience, are doubtless ready to speak as to the importance and advantage of underground conveyance by steam power.

This subject has been ably and largely treated with reference to friction and other important questions, in a paper read by the President of this Institute, and which I would strongly recommend to the notice of those interested in this question. The paper is published in the "Transactions" of 1854–5 of this Institute.

To prove to the meeting the great necessity of an improvement in this particular, so far as this district is concerned, I will make mention of three actual cases of the present excessive cost of underground conveyance.

Pit No. 1 is working in a seam of coal three feet three inches thick. Three roads are driven out, averaging about 400 yards each in length. Eight ponies and drivers are employed, the roads inclining against the load. Only one skip, containing about seven cwts. of coal, can be

brought out at one time; and about forty tons per day is all that can be raised. Thus, working five days per week, the cost of raising 200 tons would be—

Eight ponies, at 15s. per week - - -	£6	0	0
Eight drivers, five days each, at 2s. 6d. - -	5	0	0
Wear and tear of horses, tackle, &c. - -	1	0	0
	£12	0	0

being a little over 1s. 2d. per ton.

Pit No. 2 is working in a five-feet seam of coal. Four roads are used, averaging from 400 to 500 yards each. Sixteen horses and drivers are employed. The roads here also incline against the load, so that not more than one skip at a time can be brought out; and about 600 tons per week are raised. Here the cost of underground conveyance is—

Sixteen horses, at 18s. per week each - -	£14	8	0
Sixteen drivers, six days each, at 2s. 6d. per day,	12	0	0
Wear and tear - - - - - - -	2	0	0
	£28	8	0

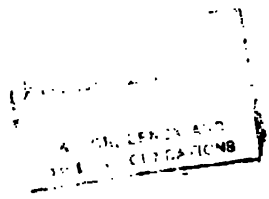
or nearly 1s. per ton.

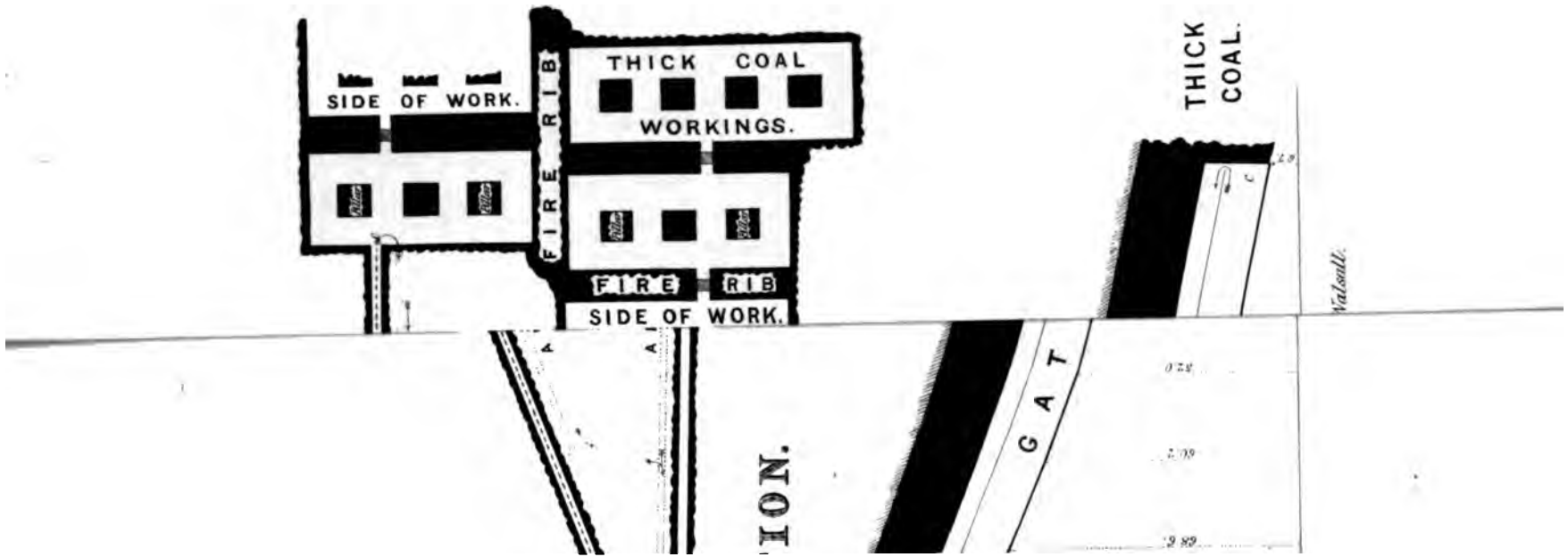
Case No. 3 is a pit working in an ironstone measure. There are three roads, averaging 300 yards each. Nine ponies are employed, and the weekly quantity of ironstone raised is 85 tons, costing, in underground conveyance—

Nine ponies, at 15s. per week each - -	£6	15	0
Nine drivers, at 2s. 6d. per day each, six days,	6	15	0
Wear and tear - - - - -	1	0	0
	£14	10	0

i.e., 3s. 6d. per ton.

In the latter two cases, the roads being "goaf" roads, and the length of them continually increasing as the face of work extends farther from the shaft, the expenses of conveyance are also on the increase; and, indeed, these expenses have now become so heavy, that it is proposed to sink new shafts, as being more economical than making any farther advance on the present charter. But, now, if in each case an engine were put down, the cost of which would certainly fall below that of sinking the new shafts, and if the workings were duly extended, with the aid of half the number of ponies now employed, the quantity raised would be more than doubled, and the rate of underground conveyance,




SIDE OF WORK.
FIRE RIB
THICK COAL
WORKINGS.
FIRE
RIB
SIDE OF WORK.
THICK
COAL.
GAT
Walsall.

The engine was placed down by the present lessees, which, with the employment of three horses, can now convey from 180 to 200 tons per day to the shaft, at a cost of 3d. per ton, being 9d. per ton less than by the original mode of conveyance.

I will here give a description of the engine fixed down this pit, which the accompanying drawings illustrate, and which show the possibility of engines being fixed and used under very difficult circumstances, and that too without risk or continual expense. But before doing so, I would remark that the Heath Pits were sunk many years ago, and the coal worked from these shafts up to the point marked "goaf" on plan No. I., the coal beyond that point being then abandoned. The shafts were afterwards sunk lower, and the road from A to B crossing the measures under the "thick coal" workings was driven so as to recover the coal before abandoned. This road was continued in the seam to the boundary in the deep of the mine forming the road, of which a section is given, plan No. I. The engine and boiler are placed underground about 360 yards from the bottom of the shaft, which is over 300 yards in depth. The construction is what is called a self-contained engine, the whole of the machinery being placed upon bed-plates, rendering it capable of being readily removed from place to place, and taking up as little space as possible, both of which are requisites in such application of power. Two cylinders are used, and likewise a fly-wheel, steadiness of action being extremely desirable in such cases, especially where wire ropes are used. Two rope drums are used, which are capable of being attached or detached in or out of gear, to run freely round upon the carriages when the rope is dragged out from the engine, and to be attached when the power of the engine is applied to pull the skips up the incline.

It is not necessary to give any detailed description of the machinery, as this will be sufficiently understood from the plan.

Drawing No. I. shows the plan and section of the roads. The bank head, at the top of the incline B, is 360 yards from the bottom of the shaft, and about seventy feet above it at A, the average inclination thus being about one in fifteen. The road from the bank head at B, to the bottom of the incline at C, is 400 yards, with an inclination of one in fifteen. The former part of the road originally was divided into two stages, worked by one horse to each stage; and the latter into four equal stages, and three horses to each stage, bringing up one skip at a time.

Plan No. II. shows, on a large scale, the arrangement, of wagon roads at the shaft on the left of the dotted line IH, and of the engine and

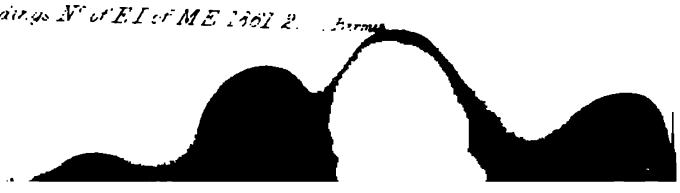
boiler on the other side IH, which are placed at the bank-head B. Much description here is not necessary. It will be seen that two horizontal sheaves or pulleys are fixed in a line as near as possible to face each road they have to work, difficulties rendering it impossible to arrange the drums otherwise. The drum on the right of the engine works the rope which passes round the pulley opposite, and works the incline or road to the shaft A, brakes down three skips at a time into the loaded wagon way, the rope being detached and hooked on to the empty wagons which are always ready on the empty wagon way, and the engine drags them up to the bank-head, and the rope is then unhooked from the empty ones and put to the loaded skips as before. The rope which works the back road is attached to the other drum on the left of the engine: this brakes down the empty skips to the different junctions shown upon plan No. I., and marked by the letters C, D, E, and F, to which places horses deliver the loaded skips. The engine drags three skips at a time from each station.

It is an unusual thing for a steam engine and boiler to be placed 360 yards from the bottom of a shaft in a solid block of coal of thirty feet in thickness. Great care is required in fixing an engine and boiler in such a position, in order to prevent the coal taking fire. Brickwork is necessary for this purpose, and also arranged in such a manner as to resist superincumbent pressure as well as pressure from every other direction. These two important points had to be well considered in the present case.

It will be seen from plan No. II. that the engines are placed on one side of the main gate road, and the boiler on the other, the distance between the two being about 100 feet—the steam passing over the main road in pipes, and the exhaust steam being conveyed from the engine over the same road and along the side of the boiler into the smoke flue, and joining the return air at A. To insure a safe place for the boiler, the coal was taken out to allow of an arch of brickwork of eighteen feet diameter being put in, which is 14 inches thick, arched in every direction to resist the weight, as shown in the sections. Two feet thickness of sand is also put on all sides between the brickwork and the coal, not only for the purpose of preventing fire and a current of air passing through the brickwork, but also of causing the pressure to be equally distributed, and so to prevent any crack in the brickwork, which object has been fully attained in this instance.

Cross section on the line C D, plan No. II., and the longitudinal section on the line A B, will sufficiently explain this arched brick-work, both of

Proceedings N° of E I of M E 1861 2...



the boiler and flue, into the return air-course, as also the road out of the main road to the boiler. The boiler seating is then fixed in the large arch, resting only upon the bottom of such arch—a space being left on each side of the boiler for allowing a current of air to pass into the flue to keep it cool. This arrangement has answered very satisfactorily, both as regards supporting the superincumbent weight, and preventing the coal taking fire. The only instance of fire we have had was in the old air-head, shown in the cross section, which was filled up with rubbish instead of sand: sand, however, has now been substituted, and all is quite cool.

It is a source of satisfaction to be enabled to say, that we have not had the least trouble or difficulty, either with the engine or boiler, during the eighteen months they have been at work.

I trust, however, that this description of the Heath Pit and engine will not divert the mind of the meeting from that particular point or subject which it has been my aim to bring forward. If what I have said be the means of drawing the attention of the practical men in this district to the importance, and, indeed, the necessity, of the introduction of steam power into our pits, and if, moreover, I can induce them practically to test the soundness of my views and experience in reference to this matter, I shall feel that I have not in vain intruded myself upon your notice to-day.

DISCUSSION

ON

MR. BAILEY'S PAPER ON UNDERGROUND CONVEYANCE.

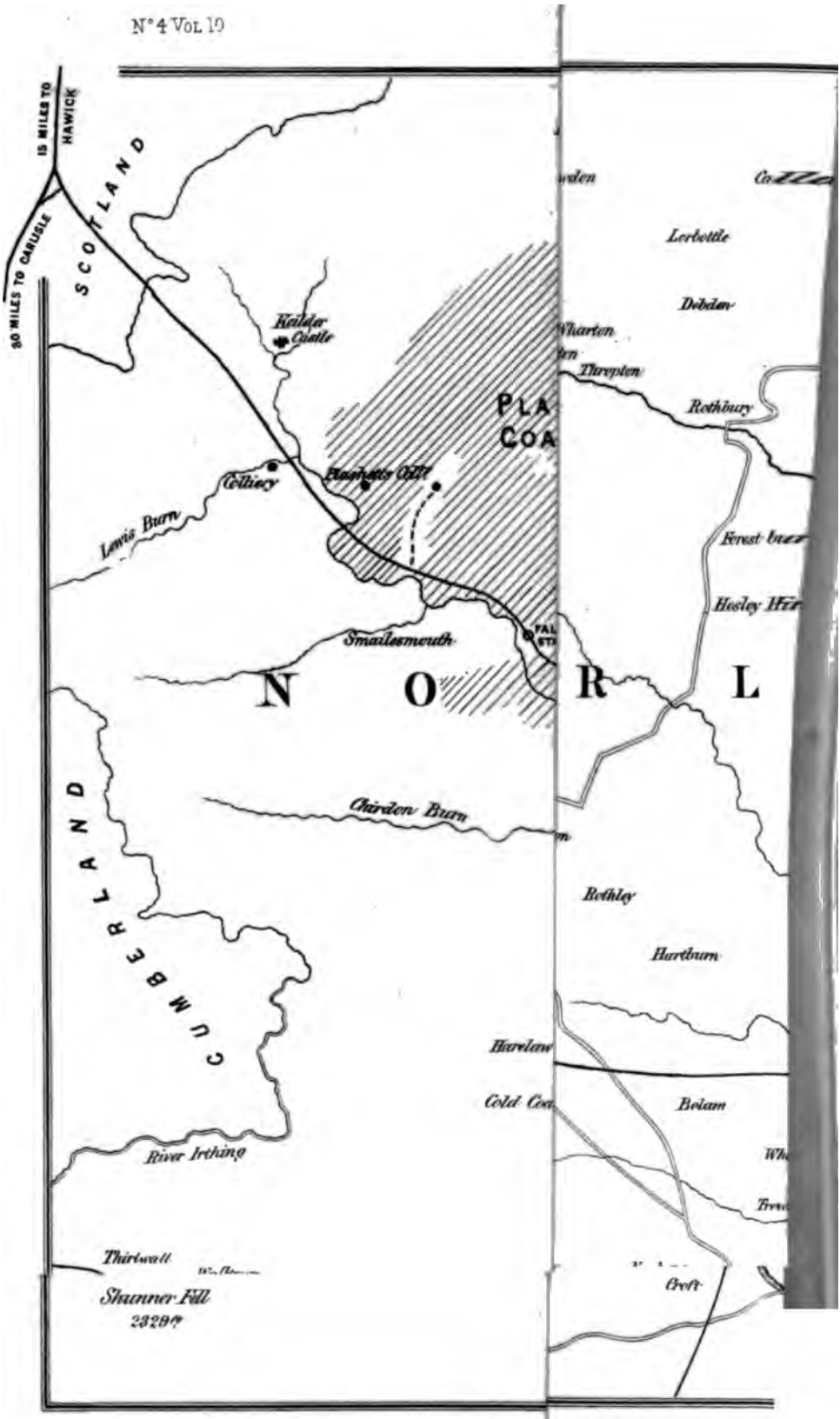
The PRESIDENT—Gentlemen, I shall be glad to hear any observations which any members of the Institute wish to make on Mr. Bailey's interesting communication.

Mr. WOODHOUSE—I am quite sure that you will agree with me, that the paper which has just been read to us by Mr. Bailey, is one which contains matter of the greatest interest and importance to us all. (Hear, hear.) Although the conveniences for the drawing of coal underground may be known to gentlemen who have long ago adopted a mode in the north of England, perfectly simple, and which enables them to reduce, almost to a fractional calculation, the cost per ton per mile of the conveyance of coal underground, yet we know that in South Staffordshire, where the mining district is small in extent and limited as to its production, underground conveyance by steam power is very rare indeed. I happen to know something of the collieries which have been referred to in the able paper which has been read to the meeting by Mr. Bailey, and I can bear him out fully in what he has said with reference to the immense improvement which has been effected in the conveyance of coal in the mine in question, by the application of the steam engine. I believe that I am correct in saying, that up to the time that Mr. Bailey assumed the control of these works, they employed no less than fourteen or fifteen horses in hauling the coal up an inclined plane at enormous trouble, flogging and whipping the horses all the way, and being obliged, when they were going down again, to use a chain for the purpose of preventing the wagons from overrunning the horses. We can all calculate what a saving there must have been by the substitution of steam for horse power, when fourteen or fifteen horses were obliged to be employed in the mine, because we know that the cost of that number of horses' per

week must be very considerable. My own impression is, that the cost of each horse would represent something like £1000 of capital. I do not think you can find a horse, certainly you cannot keep him in the mine at a less cost than £1 per week. Now £1 per week represents the interest at £5 per cent. per annum of £1000, no matter, therefore, how limited your mines in South Staffordshire may be in extent, or how short may be the roads underground in this or other districts, it is of immense importance, in these days of competition, to employ as cheap a power as possible for the purpose of underground haulage. The cheapest power in some cases is that of a self-acting plane; in other cases, haulage by means of a steam engine. And here I may say, that it does not matter how small the steam engine may be, because even where the distance up which the coal is to be hauled is only 100 yards, a steam engine may be used with advantage and a due regard to economy. It would be out of place for me to occupy your attention at any great length upon this subject, and therefore I will simply say, that I can bear the highest testimony to the value of Mr. Bailey's suggestions, and I am certain that you will agree with me in thinking that he is entitled to the best thanks of this meeting for the very excellent paper which he has read. (Cheers.)

The PRESIDENT—I should be happy if any other gentleman who has had experience of underground engines, and is acquainted with their cost of working as compared with the cost of horse power, would address the meeting; for I am afraid that, as I have already troubled you to such an extent, any remarks of mine will be tedious. (No, no.) I can only say that I am extremely glad that we have had such a paper from Mr. Bailey. I have paid great attention, as you may perhaps be aware, to this subject, which I consider one of very great importance; and I feel convinced that the suggestions which have been thrown out by Mr. Bailey will, if they are generally adopted, be attended with very advantageous effects. So far as my experience goes, I think that when there are three horses required to do any amount of underground conveyance, it is high time to consider whether a steam engine ought not to be employed; but, certainly, wherever five horses are required, there ought to be no hesitation as to the propriety of substituting engine for horse power; for there are very few places indeed where, if five horses are employed for haulage purposes underground, it would not be advantageous to use engine power. And here let me say, that it is not such a formidable matter as most persons conceive, to put an engine underground. You can get engines suitable for this purpose at a cost of something like £250 each,

or somewhere about the purchase of the horses. It is generally the simplest and best plan to put a self-contained double cylinder engine as near the bottom of the upcast pit as practicable, if the boilers are placed underground; but if the steam is taken down the pit, then the engines may be placed immediately underneath the main wagon-road, the boilers being placed at bank; and if there are more roads than one, then additional rope rolls may be used, or apparatus at each of the branch roads, to attach and detach the ropes, as coals are to be brought out of the respective branch roads. It is very often the practice to remove these engines. That can be done at a week's end, if the stations are prepared, and the steam pipes ready to be attached to the engine; and if you want to extend the engine plane, I believe you can do it in as short a space of time as from Friday to Saturday night. It is no disadvantage to branch off in different directions; and, in point of fact, in some cases, there are half a dozen different branches to various parts of the mine. I may go farther even than this, for, in one of my collieries, I have the engine used for drawing coals so arranged as to pump the water from the deep workings by means of an endless rope—the distance being about 1100 yards, and the vertical lift about twenty-five fathoms. We, therefore, use the same engine power for bringing the coals along the roads, and for pumping out the water from the deep workings. I am quite sure that, if general attention were more directed to this subject, very great savings would be effected by the use of small engines, instead of horse power, in the underground conveyance of coals. (Hear, hear, and cheers.) In vols. III. and V. of the Institute, are given two papers by me on the subject, in which it is shown that, if the main roads are properly laid out, the entire conveyance underground may be accomplished by engine instead of horse power, and by self-acting planes from the rise workings. And I believe there are several collieries in the North of England, where the coals are brought out to the bottom of the shafts without the use of horses at all—the sole motive power used being self-acting planes to the rise, and engine power along the level roads, and to the dip.



Proceedings N° of E.I of M.E. 1861-2 (Birmingham Meeting

Andrew Reid. Newcastle

ON

THE RIVERS, PORTS, AND HARBOURS

OF

THE GREAT NORTHERN COAL-FIELD,

WITH A PLAN,

SHOWING THE FACILITIES OF TRANSIT POSSESSED BY NORTHERN COALOWNERS, AND THE BENEFITS THAT WILL ACCRUE FROM THE PROPOSED IMPROVEMENTS OF THE RIVER TYNE.

By THOMAS YOUNG HALL, Newcastle-upon-Tyne.

The object of the following paper is to show that the river Tyne, by its position, its depth of water, and its general facilities for shipment to all parts of the world, is the natural outlet of the greater portion of the mineral produce of the Great Northern Coal-field, and a convenient shipping place for the clay and ironstone districts of Cleveland.

The Great Northern Coal-field extends from the river Coquet to Hartlepool, and is about forty-eight miles long by about twenty-four miles broad on the average, its area being calculated at about 800 square miles, containing about 8200 millions of tons of workable seams of coal. Six rivers, of greater or lesser magnitude, run through it in various places, which, with several sea-ports, afford facilities for the shipment of its produce.

The Great Northern is by far the largest exporting coal-field in Great Britain. France, which takes from this country 1,364,872 tons of the mineral, derives the most of it, viz., 867,901 tons, from the Tyne and other ports on the north-east coast; and America, 3000 miles distant, and with extensive coal-beds of her own, imports 580,961 tons from Great Britain, of which the Great Northern Coal-field supplies about 200,000 tons, the remainder being obtained from the west coast and Wales.

The first of the rivers in this field, marked No. 1 on the plan, is at its northern extremity, and is called the Coquet. At the eastern end of this river is the harbour of Amble or Warkworth, a shipping place of limited extent, and containing but small depth of water—seldom more than thirteen feet six inches at spring tides. A little farther southward, say about twelve miles, is the hitherto unimportant river Wansbeck, No. 2. About three miles farther is the important river and harbour of Blyth, No. 3. Then we come to the main artery of the field, the river Tyne, six miles south of the Blyth, and running into the sea at Tynemouth, No. 4. Six miles farther south is the next most important, in point of size and accommodation—the Wear, running into the sea at Sunderland, No. 5. And twenty miles farther south, near what is called the southern limit of the field, we have the Tees, No. 8. Besides these, there are shipping places at Seaton Sluice, near Blyth, No. 3*a*; Port Seaham, No. 6; and the two Hartlepools, No. 7.

The rivers and harbours situated north of the Tyne will, along with the latter river, command the great bulk of coal that may hereafter be worked out of the steam coal district, through which they run, and which is distinguished on the plan by a shading of yellow. It contains about 127 square miles of coal, equivalent to 1400 millions of tons of that mineral. In this calculation are included twenty square miles under the sea, opposite North Seaton new colliery, and extending north and south of the mouth of the Wansbeck river, the coal in which may be taken to be as good or better than any that has heretofore been worked in that district. The three classes of coal into which the district is divided, come under the denomination of white ash steam coal.

For greater distinction, we subdivide this territory into three districts, marked A, B, C, on the plan.

The Blyth district, C, which may be denominated the first class or best steam coal district, extends for about a mile or two north of the mouth of the Wansbeck, and contains ninety square miles, including a portion of the twenty miles under the sea. In this subdivision a considerable number of pits, and a very large amount of capital, have been sunk during the last thirty-six years. So rapid, indeed, has been the extinction of the best steam coal workable seams, that thus far northwards very little more capital and few more new pits may be required. This rapid and satisfactory yield will have paid interest, during the last twenty-five years, upon the large capital invested at an early date by the original lessees during many unprofitable years. Many of the present owners

and lessees will, therefore, in all probability, be able to work and sell the coal cheaper under their leases (which were taken upon more favourable terms than can be had at present), than those who may have to sink new pits, at great cost, in less favourable localities, or than even those who have taken old collieries, leased for short periods at high prices, and necessarily require to realise large sums yearly for interest and redemption of capital. The owners in this district will be the most likely parties to seek the best and cheapest shipping places, and try to maintain high prices on board ship, lest their more fortunate neighbours, with only a limited investment of capital, should be able to undersell them.

This district contains about 846 millions of tons of coals. About an eighth or so of the produce may be shipped at Blyth; a small portion at the Wansbeck river, and the rest will be brought down to the Tyne. Blyth is well situated for a portion of this district. Geographically speaking, it would appear to be the natural outlet, and, moreover, both the lessees and lessors of the coal are bound by pecuniary ties to use the port as much as is compatible with their personal interests. The harbour has recently been deepened, and its sea outlet is so favourable that a ship drawing sixteen feet of water can get to sea in north-east winds as safely as she could leave the Tyne, although the latter is by six feet the deeper river. Several of the collieries whose lessors or lessees are bound, by the ties alluded to, to Sir M. W. Ridley (a large shareholder and the Lord of the Manor), are in close contiguity to this harbour, which, under present circumstances, may be called their own. It has been a harbour ever since the period of the Roman invasion, and the improvements effected and in progress will no doubt, in course of time, repay the money expended upon it. Hitherto Blyth has done the Tyne no harm, by any reduction of its shipments. Indeed, the construction of the Blyth and Tyne Railway, by producing competition and affording a means of transit from important collieries in the Blyth and adjoining districts to an excellent dock on the Tyne, has been of positive advantage to the Tyne. During last year Blyth shipped 224,451 tons of coal. This, although the largest quantity exported from that place, is only a twentieth part of the quantity exported from the Tyne. The quantity of coals led over the Blyth and Tyne Railway, in 1860, was upwards of 1,500,000 tons, from which, of course, the company derived a large revenue, so that, although the benefit to the river is considerable, the advantage to the railway is fully greater. Comparing the quantities of coal led by the West Hartlepool, Midland, North Eastern, and Blyth and Tyne companies, with the amount of each

company's capital, it will be found that the Blyth and Tyne Company gives the highest per centage on the capital expended, and is a much more profitable undertaking than any of the others. Indeed it is doubtful if a more profitable line exists in the country, and it is therefore a great boon to the coalowners.

We now come to district B, comprising Portland North Hartley Colliery, the produce of which is being extracted by a pit or two in the occupation of Messrs. Harrison & Co. The area of this portion of the steam coal-field is about twenty-three square miles, and may be said to be almost entire,—a great portion of it being unlet. The coal seams to the northward are but little proved, and where borings have been made or pits sunk, the results are not very favourable. The contents of this district will be about 320 millions of tons. The main outlet for this is the Tyne, with its docks, large steamers, and cheap shipping.

The next is a precarious district, like that of B, and as yet very little sought by speculators. It is marked A, and runs north from Widdrington to Warkworth, where the coal seams in the Northern Coal-field come to the surface and commence to enter the sea. The area of this district is about twenty-one square miles; and the total produce may be put down at 260 millions of tons. In this area no account is taken of the probable working of the coal to the dip from under the sea, although that, to all appearance, is of a better quality than the coal at the outburst generally, or within half a mile of the same. In this district there are at the present time only two collieries, viz., Radcliffe and Broomhill; both of which have been in operation about twenty-five years, in which period they have produced a very small annual yield, and have consequently been of very little importance in the northern coal trade. Radcliffe Pit is in the occupation of Messrs. Harrison and Co., and Broomhill Colliery is wrought by Messrs. Burdon and W. Barkus. Many hundreds of thousands of pounds were sunk (and a great portion of it may be said to have been thrown into the sea) by a former company in trying for about thirty years to make a sufficiently deep shipping place for Radcliffe Colliery. Had the same amount been spent in the construction of a railway to the Tyne it would have doubtless been a much more profitable expenditure. The line would probably have answered the same purpose as the Blyth and Tyne, and have been as successful an undertaking, capable of taking all the coal and other traffic from the district, and even fitted to compete with the North-Eastern Railway in the conveyance from thence of other merchandize.

As the harbour can only accommodate small ships, at spring tides, drawing thirteen or fourteen feet of water, the Broomhill coal owners often find it advantageous to send a portion of their limited produce to the Tyne, and even to those more distant shipping places the North and South Docks, at Sunderland; in which operation they have to pay the extra expense of public lines of railway for thirty or forty miles, in order to obtain larger ships and greater facilities for shipment.

There are, in addition to these, a few patches of coal beyond the outburst of the recognized field. They principally overlie the carboniferous limestone in the northern and south-western parts of Northumberland, and are wrought by means of seventy-seven pits, mostly for local or landsale purposes. Amongst them may be mentioned Shilbottle, Scremerston, Newton-on-the-Moor, Netherwitton, the Plashetts, Acomb, Fallowfield, Chipchase, Allerwash, Stubleck, Haltwhistle, Blenkinsop, Brinkburn, Tynedale Fell. There are others farther north, but as yet they are of little importance.

We now come to the portion marked D, coloured pink on the plan. This district lies south of the steam coal district and extends along the north side of the Tyne from Tynemouth to Newcastle, and thence to Bywell, a distance of more than twenty miles. It joins the steam coal at Seaton Sluice (No. 3*a*), four or five miles northwards of the river Tyne, and runs with it for a distance of eight or ten miles from the sea, westward. The portion that borders on the Tyne east of Newcastle has been wrought for centuries. The area of this district may be estimated at 162 square miles.

In former times this Main Coal Seam was considered the best coal in the north, and a great portion of it was wrought out while the Hutton Seam in the Wear was coming into repute. The small remaining portion, with the seams of coal that lie underneath it, will yield 1200 millions of tons. They are, however, but little worked at present, borings and winnings having proved them to be of a doubtful character, as to profitable speculation, and not very suitable for either household or steam purposes,* at least as long as the better seams last.

This Main Coal, the seam of which was six feet thick, was known to our ancestors, as it is to us, by the name of the Wallsend household coal. The large main dyke or fault, H, coloured vermillion on the plan, runs through the centre of it and throws the various seams of coal con-

* For borings *vide* pages 277 to 283 in Vol. II. of the Institute's "Transactions."

siderably down towards the north. At the portion west of Towneley and Stella the seams on the north are only about forty fathoms deeper than on the south; but in the east, as at Denton, Kenton, Gosforth, Killingworth, and Earsdon, near the sea, the same seams of coal are from 90 to 180 fathoms deeper on the north than they are on the south side of the dyke.

The working on the north or dip side, either in the western district, after the dyke has crossed the Tyne at Lemington, or in the eastern portion nearer the sea, has been attended with extra expense by reason of the pits having been sunk to the rise, in order to obtain the more profitable coal quickly, and at less cost. The owners are, therefore, now working that which remains of the best coal seams, by means of fixed underground engines, from the dip of the main dyke, at an angle of one in four. Gosforth Colliery is sunk on the south side of the dyke, and a drift has been driven through it to work the coal to the north of it. The same course has been adopted in three places in the Towneley and Stella Pits; the object being to obtain the good household coal on the north side, without sinking new shafts at the root of the dyke, where much water is certain to be encountered, and very great expense entailed.

A large number of the pits in this district, on the south side of the dyke, and extending from Tynemouth to Benwell Colliery, are abandoned. A limited portion of a royalty called Montagu Main, near the entrance to Kitty's Stone Drift, which runs from the level of the Tyne near Lemington through the dyke northwards underneath Denton, had lain dormant for forty years, until opened out about a year ago. Pits also at the north of the dyke, at Newburn, Callerton, Fawdon, and Wideopen, have been closed; many of them being given up because they proved unprofitable, and others through irruption of water. At the present time the accumulation of water in pits below Newcastle, on both sides of the Tyne, is enormous, and is increasing. If it be not pumped out, it will by and by rise to its highest level, and affect other pits now or lately in operation. A list of the pits drowned out is as follows:—Whitley Colliery (two pits), Percy Main Colliery (two pits), Willington Colliery (two pits), Wallsend Colliery (three pits), St. Peter's, Heaton Colliery*

* A pit at the Ouseburn belonging to this royalty was laid in by the rise of water to the bottom of the shaft so recently as last year. The bottom of this pit was only thirty yards from the surface. The pits at Jarrow are 150, at Percy Main 135, and at Wallsend 120 fathoms deep. They are nearly filled with water, which will shortly rise to the level of the Tyne like the Ouseburn pit, which, it should be stated, is not at present in communication with them.

(two pits), St. Lawrence Colliery (one pit), and St. Anthony's Colliery (one pit). The abandoned collieries are Earsdon, Holywell, Shiremoor, Benwell, Newburn, High Elswick, Callerton, Wideopen, and Fawdon; several of which have more than one pit abandoned. Low Elswick Colliery, after many years' abandonment, has been reöpened, and an old pit or two, near North Shields, are being reworked in the upper seams in a small way for landsale purposes.

These pits comprise a large district, and if ever they are reworked, as may not be improbable in the course of the next century, when we may expect the steam coal, and the better and more profitable districts to be nearly exhausted, they will find the nearest, best, and cheapest outlet for shipment at the Tyne.

We have now nearly disposed of the coal-field north of the Tyne, and it needs no special argument to show that the Tyne is, and will continue to be, the natural and cheapest main outlet for the produce thereof; whilst it may hereafter be the outlet for coal that we do not now take into account, but *which may be wrought from under the sea or brought up shafts that could easily be sunk in the sea itself, or brought from pits at a great distance.*

The total amount of coal in these four districts will be about 2,626,000,000 of tons, including only twenty-one square miles of the seams under the sea.

The lessors or lessees throughout these districts will find it to their interest to seek the Tyne and its docks as their outlet. From thence the produce, with the exception of such small portions as may be sent to Blyth harbour, Seaton Sluice, Radcliffe harbour, and the mouth of the Wansbeck, will be shipped for at least the next 150 years, for the millions of money recently and about to be expended upon the Tyne will ever enable it to offer accommodation superior to any other river or harbour on the north-east coast.

We have said that we estimate the produce in these four districts at 2,626,000,000 of tons; about one-fifth or more may in all cases be deducted, to allow for losses, colliery consumption, and in certain districts one-sixth more for coal stowed away underground as waste and irrecoverable. By dividing the amount left by the present yearly production, the duration of this portion of the Great Northern Coal-field will be determined. At the rate of only seven millions of tons yearly, the seams unwrought and those remaining in the "drowned out" pits, without taking into account the small seams, varying in thickness from twelve to

twenty-four inches, would yield coal for about two hundred and twenty-two years. The probability is, however, that as the great demand for the steam coal will tend to a greater increase in its production, and hence, that the annual yield from this district will be greater than it has been during the last twenty years, the portion under consideration may be worked out in less than half that period, and the trade of the Tyne thereby receive still greater and more rapid benefit. If one-half more than the present quantity be the rate of working, the income of the Commissioners of the Tyne will be nearly doubled, particularly as the yearly interest and the expense of shipment are pretty much the same on a small as on a large quantity, and the duration of this portion of the coal-field will be reduced to 150 years or thereabouts.

To show the rapid decrease by excavation, let us take old Cramlington Colliery, belonging to Messrs. Lamb and Potter, the average working at which, for the last thirty-three years, has been about 360,000 tons or cubic yards yearly; let us calculate an extraction of 240,000 tons yearly for Mr. Joseph Laycock's pits at Seghill: and estimating the best coal seams at six feet thick, these collieries will have excavated in the aggregate at least 2600 acres of coal. If the coal seams were only three feet thick, more than 5200 acres would have been extracted during this short period. There are about twenty other collieries doing a similar amount of work in this steam coal district.

I now come to that portion of the coal-field which is situate south of the Tyne, in the county of Durham, and which comprises an area of 470 square miles, or the better half of the whole northern field.

The district marked E, and coloured green, comprises different qualities of coal suited for steam, household, coking, and gas purposes. In this district are twelve pits that in former times were largely wrought, but are now drowned out, or abandoned from other causes. Of these, there are inundated, St. Hilda, Manor Wallsend, Jarrow, Hebburn, and Oakwellgate; and abandoned, Norwood, Ravensworth Vale, Sheriff Hill Collieries, and one or two others; several of them having two pits each. These, with the twenty-four enumerated on the north side of the river, make in the aggregate about thirty-six collieries rendered unworkable, principally by the irruption of water, after the best main Wallsend seam had been nearly exhausted.*

* As a set-off, however, I may mention that, in the large unwrought portion of this locality, near to the Tyne Docks, a new pit called the Harton has been got into operation, after about ten years' labour and great expense in sinking, &c. It is working profitably and on an extensive scale. An attempt was made by

The present natural outlet for shipment for the whole of this district (as will be seen by the plan) is the Tyne and its docks. Should it be objected that Monkwearmouth Pit certainly could not find a *natural* outlet in the Tyne, the answer is, that the difficulty of shipment in the North Dock at the mouth of the Wear is so great, and (from the want of a competent railroad bridge) the situation of the South Dock is so much less convenient than the Tyne Dock at Jarrow, that, although the owners have a good private shipping place of their own on the Wear, in close contiguity to their pits, yet, after the Tyne is improved, the Monkwearmouth Company may find it their interest, for a portion of their trade, to avail themselves of the superior resources and cheaper freights enjoyed by their neighbours on the Tyne.

It is in this portion of the coal-field that the projected river improvements will be attended by the most beneficial results. There are already extensive docks on the south side of the Tyne at Jarrow, and public railways are projected along the north side of the river, and also through the Team and Derwent Valleys on the south and west, in connection with the proposed western dock, described hereafter.

When the plans of Mr. Ure, the River Engineer, are fully carried out, ships and steamers of 2000 or 3000 tons will be able to come into these docks; whilst ships of 600 tons, and steam vessels of 1200 tons, will be able to ascend, with ease and economy, four or five miles above the High Level Bridge, into the very centre of the western portion of this district, where cheap coal, suitable for household, coking, and gas purposes, will for a long time be obtained in great abundance. Coalowners will no longer have to carry their coals by railway or in keels, for long distances, to the ships moored in the Tyne, and so the prosperity of the town and trade of Newcastle, as well as that of the whole of the Tyne, will be immensely increased, and Newcastle will be kept as the central point for the business matters of the river and the coal trade.

This plan of the engineer, for which an Act of Parliament has been obtained, will, as we have stated, deepen the channel from Tynemouth Bar to Newburn, shorten the distance, and generally cheapen the transit.

the owners of Harton Colliery, a few years ago, to resume operations at Jarrow Colliery, also belonging to them, by drawing off the water. Upwards of £22,000 were spent in that attempt, but it was ultimately abandoned without a single ton of coal having been obtained. Similar efforts were made at Hebburn and Wallsend, and they also proved unsuccessful. The late Mr. Thomas John Taylor proposed a plan for draining the whole of the drowned-out pits, and gave notice of his intention to apply to Parliament for an act for that purpose; but the plan was considered to be somewhat premature by the owners, whose assistance and concurrence was necessary, and the bill was withdrawn a short time after the death of that lamented gentleman.

By temporary barriers, placed so as to throw the river into a narrower channel, increasing thereby the scouring power of the tide, and by the use of the new dredger of 60-horse power (which cost £40,000), and other dredgers, the river to the west of Newcastle can, in the course of two or three years, be rendered deeper by at least eight feet than it is at present. Tynemouth Bar can be pushed forward into ten feet deeper water, making it thirty-one feet in depth at high water of ordinary spring tides. The stone dyke barrier across the Tyne below Lemington (thirteen miles west from Tynemouth) can be easily blown up for about 100 yards or so, and Newcastle Old Bridge—a great obstruction to navigation—be pulled down and reconstructed on better principles. There is no good reason, therefore, why we should not, in a very few years, have even thirty-one feet of water at Tynemouth Bar; and from Newcastle to Blaydon, eight feet more than there is at present. This would render the Tyne, as a coal port, infinitely superior to the river Wear and its docks, or any other river, port, or harbour on this coast, and (coal being obtainable at less cost) as good or better than Cardiff, Swansea, or Newport on the coast of Wales, or probably any other harbour in the kingdom. At J, twelve miles from the sea, by cutting off a mile or thereabouts of a deep but circuitous part of the river, an excellent and convenient river dock, and a shipping depôt of great extent, could be formed. The water at the wharf there, erected and occupied by the writer, has been, from time immemorial, and without any recourse to dredging operations, as deep or deeper than Tynemouth Bar; and two or three public railways, and several good turnpike roads, intersect each other at this point upon a common level, and only a few feet above the tidal water. This dock will accommodate, and, indeed, greatly develope the Blaydon and contiguous districts, in which are the royalties under the Chopple Woods, and the collieries of Whickham, Winlaton, Garesfield, Chopwell, Crawcrook, Stella, Ryton, Towneley, Shibdon, and Blaydon, in the county of Durham, and Mickley, Prudhoe, Wylam, Elteringham, Lemington, Walbottle, Montagu Main, Callerton, Fawdon, Newburn, Throckley, Heddon Banks, Horsley, Throckley Fell, &c., in Northumberland, comprising an area of 160 square miles of coal-producing country (coloured green and chequered on the plan), all within easy distance of the proposed dock. The transit over public railways in this neighbourhood will be shortened, or almost entirely dispensed with. In fact, a large portion of the produce of the district will only have to run over from one to two or three miles of private railway to enter the

dock J. The Great Pontop, Lintz, and Marley Hill coal districts, with their railways, whose extreme points are not farther distant than five or six miles, would have the option of coming to this dock, instead of going double the distance to the Tyne Docks. The Marley Hill Colliery Railway, about six miles in length, which is connected with a large number of pits, runs down to the Tyne, in the Team Valley, in conjunction with the Newcastle and Carlisle Railway. It is within a very short distance, say two miles, of the proposed dock, and could easily be brought to it, where it is expected large steamers and other ships will be accommodated.

The remaining districts, marked F (brown) and G (black), complete the 470 square miles of the Durham district. Each of these districts, comprises 152 square miles of well-defined coal measures and contains 2200 millions of tons of coal, principally of the household variety. About twenty square miles of coal under the sea, opposite Seaham and Ryhope, are included in this calculation.

The district marked F lies on the north side of the Wear, and extends from the south of Monkwearmouth North Docks, by way of Chester-le-Street to Towlaw, Witton Park, and Conside Iron Works. It consists principally of a similar coal to that contained in the district marked E.

The coal on the south side of the Wear, and west from Sunderland, by way of Pensher and Chester-le-Street to Durham and Bishop Auckland, has been, and continues to be, extensively worked out of the best seams, and is good and suitable for various markets. The southern boundary of this district (see plan) is as yet imperfectly defined, but the coal northwards has been safely proved in all directions. The seams now working out are principally the Hutton Main and Five-quarter Seams, which yield the best household coal, and most of the other seams characteristic of the Great Northern Coal-field underlie them in a workable state. The boundary projects south until one of the seams, it is stated, runs up against a limestone, as is seen in the workings at Castle Eden Pit. In other words this southern boundary, which may form the subject of another paper, is described by an imaginary line extending from Barnard Castle, on the Tees, through Raby Park, Cockfield Fell, Thickley, Heighington, Simpastures, Sedgefield, and South Wingate Colliery (now abandoned, near Hutton Henry), on to Hestleton Dean, entering the sea four miles north of Hartlepool Docks. South of these points many borings have been made and pits opened, but the results have invariably been unsuccessful. This latter district, like the former one, is conve-

niently situate for the river Wear and its docks and the several ports or harbours of Seaham (6), Old and West Hartlepool (7), and the Tees river, with its drops at Port Clarence and dock at Middlesbro' (8). But each of the districts avails itself of the cheap railway transit to the Tyne, for shipping a considerable portion of its produce, and may hereafter do so to a much greater extent. Even the Marchioness of Londonderry and Earl Durham, who possess special means of access to the Wear and Seaham, send coals to the Tyne—the Marchioness, from her pits at East, Middle and West Rainton, Pensher, Pittington, Old Durham, and Framwellgate Moor Collieries; and Lord Durham from Newbottle, Lambton, Lumley, Shadforth, Littletown, Fatfield, Biddick, and other collieries. We believe that coal finds its way to the Tyne, too, from Kepier, Belmont Grange, Whitwell, Shincliffe, Cassop, Ferryhill, Chilton, and Tirsdale; and the collieries, belonging to various owners, of Haswell, Shotton, South Hetton, Thornley, Ludworth, Tees Wallsend, Eldon, Adelaide, West Auckland, Copley Bent, Brancepeth, Brandon West Pits, &c. Most of these pits have, independently of the privilege of coming to the Tyne, direct communication with Sunderland, the Hartlepools, Middlesbro', and Port Clarence. Castle Eden, Trimdon, Wingate, Shotton, Thornley, and Ludworth, are near Hartlepool Docks. Ryhope Colliery is only about two miles from Sunderland South Docks, and ships its produce (which is already large, and will, in the writer's opinion, shortly be doubled) at these docks, adding largely to the Wear exportation. The "Ryhope" screw collier, belonging to the Messrs. Taylor, the owners of this colliery, made fifty-four voyages to London within a year, travelling a distance of 32,400 miles in that time. Thirty years ago nine or ten was the ordinary number of voyages performed by smaller ships trading between the same ports. Monkwearmouth sends to the North Docks in the same river; and Seaton, Seaham, and Murton* Collieries ship all, or the greater portion, at Seaham; while South Hetton finds outlets at Seaham, Sunderland, and Old Hartlepool.

* The expense of winning Murton Colliery will suggest to strangers a striking contrast, when they consider the ease and rapidity with which pits are sunk in Staffordshire and other parts of the kingdom. The money invested in sinking Murton Pit is said to have been £400,000, principally in consequence of difficulties experienced in sinking through sand only a few yards thick. These obstructions were of such a difficult character to the Haswell owners, that they were forced to abandon a pit which they had commenced to sink in this part of their coal-field, after spending £60,000 or so; and in a similar manner a corresponding outlay may have been incurred at Old Lyons Hetton, as far back as the year 1820, and which also was abandoned. The same may be said of Lord Howdon's Wingate Castle Eden New Pit. South Wingate Pit, which was sunk and worked coal for a few years, was abandoned about the same period as the former one. Each of

In this district is the important river Wear (5), with good docks at the southern side of its debouchure into the sea. The tidal water reaches from Sunderland to a point beyond Chester-le-Street, and the river itself extends, by way of Brancepeth and Witton-le-Wear, to Wolsingham, near Stanhope. Near this latter place the lowest seams of the Great Northern Coal-measures crop out to the surface above the carboniferous limestone.†

Between the River Wear and its Docks (5) and the Middlesbro' Docks (8), there are also the Port of Seaham (6), four miles south of Sunderland, and the two Hartlepools (7), eight miles farther in the same direction, each of which takes a portion of the coal from the districts E, F, and G. A deduction being made, as before, for previous excavation, losses, contingencies in working, &c., these 470 square miles will, at the present rate of working in Durham (say 15,250,000 tons per annum), last for 222 years to come. Add the 7,000,000 tons annually derived from the 280 square miles in Northumberland, and we have an aggregate yield of 22,250,000 tons yearly, which is the present rate of working out of the whole 800 square miles, containing about 200 working pits in the best positions. Deducting one-half of the whole for home or local consumption, there remains about 11,000,000 tons to be shipped yearly, nearly 5,000,000 tons of which are placed on board in the Tyne, and the remaining 6,000,000 in the other eight or nine rivers, harbours, and ports on this coast. But the probability is, that if these good coal producing districts continue to increase their trade as they have done during the last five years, the Tyne and adjoining ports will be benefited much more rapidly, whilst the coal-fields will diminish in the like ratio. Moreover, the probability being, that in districts waterlogged or left unworked certain portions

them was sacrificed at a great loss to the owners, as were also three or four others at Mainsforth, Garmondsway, Thickley, and Merrington. A pit sunk when the writer was mining engineer for the South Hetton owners, and now working extensively at a mile to the dip of Haswell Pit (abandoned), cost the South Hetton owners about £100,000, including upwards of four miles of railway to Seaham Harbour, and a branch about a mile long to join the Hartlepool Railway, at or near Haswell. It was at South Hetton Pit that the writer, in the year 1832, introduced into the Great Northern Coal-field the working of coals by tub and cage system, which has been stated by the writer to have effected, upon an annual yield of 13,000,000 tons, a saving to the coalowners of collieries in Durham and Northumberland, of not less than £1,000,000. The annual produce has now increased to 22,250,000 tons. A description, with plans and models of this system, are exhibited by the writer at this meeting, along with views of the old plan of bringing up coals in corves or baskets, which system is now entirely abandoned in this and other coal districts of Great Britain, and in several foreign coal-producing countries too.

† This limestone is quarried at the surface at Westerlee, near Wolsingham, where it is upwards of 1100 feet above the sea level; while under Seaham, Ryhope, Sunderland, and Tynemouth, this same limestone lies about 3000 feet below the sea level; also about the like distance below the magnesian limestone.

will never be resumed, this period will be still farther reduced, so that hereafter coals may be brought from a great distance to the large factories, &c., that will then exist in the neighbourhood of the Tyne and the adjacent ports, as well as to the large ships that will ever float in their docks and harbours.

The rivers, ports, and harbours in this southern part of the coal-field are those which enter most largely into competition with the Tyne. The Wear, there can be no doubt, might temporarily be made into a formidable competitor with the river to which in ancient charters it figures as a mere creek. The tidal water has been much improved of late, but the River Wear Commissioners have expended the greater portion of their income in carrying on the South Dock, which, without such assistance, was not likely to pay a remunerative interest upon the capital invested. Although much has been said recently about the comparative depths of water at Tynemouth Bar and Sunderland South Dock, there is every reason to believe that the reports have been exaggerated; but whether misrepresented or not, the Tyne, as will be seen by the comparative statement at the end of this paper (Table, No. 2), keeps a-head of Sunderland, and of all other ports in the kingdom. Mr. Ure's improvements will shortly give a depth of water, say thirty-one feet, to the Tyne bar, by which means trade, which may have gone temporarily to more southern rivals, will probably be reverted into its proper channel.

The Hartlepool Docks are rising into great notoriety. The sites they occupy are the most suitable along this line of coast for establishing a dangerous competitor to the "canny" river that "carries coals to Newcastle," and had they commanded an extensive area of coal territory like the Tyne they might have become formidable. But it is doubtful whether West Hartlepool Docks and their adjuncts will prove as profitable an investment as the Tyne, which rests upon its own merits rather than upon adventitious aid.

Many years ago, when the writer was a director in the Old Hartlepool Dock and Railway, and the shares of £100 each were selling at upwards of £180, an arrangement was effected with Mr. G. Hudson, for the North-Eastern Railway Company, by which the latter leased, for thirty years, the dock and line, and engaged to pay the shareholders eight per cent. interest. Shortly after this time Mr. Ward Jackson and other influential persons projected the West Hartlepool Docks and Railway, and now instead of a public company like the Old Hartlepool Dock and Railroad Company, with a capital of only £450,000, paying eight per

cent. out of real profits, we have a company at West Hartlepool that, after investing £3,250,000 in docks, railroads, collieries, and ships, pays four and a half or five per cent. chiefly out of its profits and capital, and is applying this session to Parliament for increased borrowing powers. Under these circumstances, it will be admitted that the prestige of the Tyne has in the long run little to fear from these quarters. The Old Hartlepool Railroad and the excellent Docks of the old company are in the hands of the North-Eastern Railway Company, which, with its 800 miles of main line and branches, and a capital invested equal to £27,000,000 sterling, is a formidable competitor wherever its interests lie, and at present they are chiefly in the Tyne.

Seaham, the next port of importance in this part of the coal-field, must be considered as a private speculation. It has been constructed chiefly for the accommodation of the pits belonging to the Londonderry family and the South Hetton Company. Its construction cost upwards of £250,000, and extended over a period of about thirty years. It is probable that if its projectors had foreseen the expense and trouble involved they would have more maturely considered their plans and possibly have sought the Tyne and the Wear as much cheaper outlets for the produce they desire to accommodate.

Stockton on the Tees, as a port for the shipment of coals, has proved, in every sense of the word, a failure. The Stockton and Darlington Railway Company, thirty years ago, thought it might prove a convenient shipping place for the collieries west and south of Bishop Auckland, and great expense was incurred in improving the river, making shipping berths, laying down a railway, &c., but for twenty years it was to little purpose. A spot nearer the sea was afterwards selected, an iron suspension bridge was thrown across the Tees, and drops were erected near Middlesbro', and opposite another shipping place, known as Port Clarence. But the locality could not be made to answer, and in the monthly list of exports Stockton is "nowhere." Middlesbro' Dock has been of far more value to the iron trade than to the export coal trade. Indeed, it is upon the iron furnaces in the neighbourhood that these western coal beds and the rising town of Middlesbro' chiefly depend. The entire shipments of coal from Stockton and Middlesbro' during the year 1860 did not exceed 355,000 tons. If the deep water site upon the coast at Redcar, so well adapted for a harbour of 350 acres, had been adopted by the shareholders of the Stockton and Darlington Railway, many of whom were large coal and iron ore owners, they would have had a harbour forty feet deep

at high tide, which, while costing less than they have spent in abortive speculations in other directions, would have served the western collieries, the iron works, and all sorts of shipping—in fact, the entire navy of Great Britain could have lain there at once.

Had the old Conservators of the Tyne, when they had the means and the power in their own hands, only possessed sufficient public spirit, they might so have improved the navigation of the river, and opened out such facilities on its banks for numerous trades that would have sprung up, that there would have been no need for coal owners and iron masters to promote the formation of other shipping outlets in less favourable situations.

The rapid increase in the coal and iron trades of Durham, Northumberland, and Cleveland,* appears to require the construction of railways in Cleveland, and also south of the Tyne up the Derwent and Team Valleys, and on the north side of the river, in connection with the Blyth and Tyne Company's proposed Newcastle branch through Gosforth. Two or three railway companies have already made, and are anxious to make, lines in these localities; and the managers of so magnificent a river as the Tyne must offer every advantage, in order to prevent the farther diversion of trade, by land or other means of transit, and the waste of money upon inconvenient places which can never be able to compete with the "coaly" river.

Until the constitution, by Parliament, of the present Commissioners, this river, with its three bars, was left almost entirely to nature; and the result is shown in the opposition ports and docks that have sprung up of late years, not only close at hand, but in other parts of the kingdom.

And yet, in spite of drawbacks of every kind—whether arising from a

* The capital employed in the Great Northern Coal-field in producing 16,000,000 of tons yearly, was stated by the writer, in a paper read before the Institute on the 6th of December, 1854, to be £30,000,000 sterling, viz.:—

Pit plant	£14,000,000
Railways	10,000,000
Shipping	6,000,000
	£30,000,000

The value on board ship of the yearly produce was therein estimated (the expense of freight to London and other ports in the United Kingdom being upwards of one-half) at £13,000,000. This estimate of capital, the writer now considers, was too low, though at that time it was held to be pretty correct. Since that period, large sums have been spent in the construction of public and private railways, docks, and other conveniences for rapid shipment, within the limits of the coal-field, which cannot be estimated at less than £5,000,000 sterling—the Tyne Docks alone having cost more than three-quarters of a million. This expenditure will bring the total capital at the present day up to £35,000,000, and, in the course of a few years, the proposed improvement of the Tyne will have added another million or two to this amount.

want of public spirit in the river authorities, or the efforts made to create rival ports—the Tyne has gone on increasing its coal exportation, and has distanced all competitors. There was a regular and steady increase in the shipments of coal up to the time of the great strike of the pitmen in 1844—which marks a new era in the trade; and since that time progress has been made at the rate of 33 per cent. No other port in the kingdom can show, or is likely to show, a greater degree of prosperity, and there is no other port that can so easily be adapted to the growing wants of the trade. Tables Nos. 2, 3, and 4 at the end of this paper show the preponderance of the Tyne in this respect over every other port in the kingdom.

The new Commissioners are doing wonders, considering their means, and the fact that they have not as yet got fairly under way with various useful projects. Since their incorporation, the Commissioners have expended only a comparatively small sum, viz.:—

On the Northumberland Dock - - -	£300,000
„ Piers - - - - - - -	191,000
„ River generally, about - - -	100,000
	£511,000

But they have power to spend an additional two millions, namely:—

On the Piers - - - - - - -	£300,000
On the Tyne and Tynemouth Dock - -	1,600,000*

They have now, therefore, £2,500,000 capital additional to their large and increasing income of £100,000 per annum, available for carrying out further improvements;† and by the new act just coming into operation, this large yearly income is likely to be doubled ere many years are over. It is to be hoped that these improvements will prevent further encroachments, as we may call them, especially such as are involved in railway arrangements for carrying coals at unremunerative prices to London, and the formation of public and private railways to take coals 100 miles or more from the western division of the Northern Coal-field, to the west coast for shipment to Ireland, instead of bringing them to the Tyne,

* The Commissioners possess already three-eighths of the funds called the Coal Dues. Should they buy the balance, five-eighths, of the Corporation, their income would be increased £12,000 per year under this head alone.

† Other parties have spent as follows:—

North Eastern Railway Company, on Tyne Docks and Brandling Drops, - - - - - - - - - -	£750,000

Altogether the money invested, and to be invested, if necessary, in the improvement of the Tyne, in a short period of time, will not be less than £3,500,000.

where, generally speaking, abundance of shipping and much better prices are obtainable.

There can be no doubt that it is for want of that communication with the Tyne which is now about to be supplied, that the western coalowners are trying to ship coals at defective ports on the west coast. It becomes, therefore, a question of great interest to the proprietors of coal pits there whether they should not arrange with railway companies that are trying to amalgamate with the North Eastern Railway Company, to send on cheaper terms a great portion of their coals to those of the eastern ports which the North Eastern Company's lines command, viz.:—the Tyne, Sunderland, and Old Hartlepool Dock, in the same manner that Mr. Ward Jackson did with the West Hartlepool Dock and Clarence Railroads. For it will be seen that the distance by rail from this district to the proposed dock at J, on the Tyne, is only one-eighth of that by Tebay to the western coast, and is less than the distance to Middlesbro' Docks.

Within the last twenty-five years this western portion of the coal-field, then well known to the writer, has been much developed and opened out, but the produce has been largely consumed by the iron works, coke manufactories, &c., that have been established at no great distance, as at Conside, Witton-le-Wear, Towlaw, Tudhoe,* Darlington, Ferryhill station, and Port Clarence.

The exports of the western coal are a mere bagatelle, and the collieries in connection with the Tees have in many instances, since the opening of the Stockton and Darlington Railway, to the writer's certain knowledge, not yielded so profitable a return as was expected for the large capital invested during the first twenty years of their existence, whatever they may have done within the last ten years. In proof of this, it is only necessary to point to the fact that Tees Wallsend Blackboy and other collieries have, within the last named period, opened railway communication with the two Hartlepools and the Tyne, and find the new routes answer admirably.

In the coal mines that are on the outburst of the field, two or more of the ordinary seams run into one, so that there are only one or sometimes two workable seams of tender coal, instead of the five or so that are found in the east, below the Hutton seam. Considering their limited capacity, these seams are not very carefully dealt with, and if they continue to be

* Mr. Attwood and the Messrs. Baring have established several furnaces and rolling mills in this locality, for one of which, in particular, they obtain the best ore from an excavation that was formerly a lead mine, and which, when smelted, forms pig metal, which is exported to France at the price of about £6 per ton—more than double the average price obtained for pig metal from any other locality hereabouts.

worked as rapidly as at present, they cannot, in a district so circumscribed, be of long duration. Had the Tyne improvements been commenced thirty years sooner, the iron manufacturers in this locality, after a brief experience of inconvenience, expense, and loss, might have been induced to establish their works on the banks of the Tyne. The iron furnaces at Middlesbro' are at a distance of from twenty-six to thirty miles from the coal at Pease's West, which, moreover, is only accessible to them by public railways for long distances—a dear method of conveyance compared with that of sending the produce over a short distance to the more northern river. There are already on the banks of the Tyne the extensive iron furnaces of Walker, Jarrow, Wullsend, Lemington, Felling, Washington, Wylam, &c. And within a reasonable distance from these are, to the north, Brinkburn, on the Coquet; Haltwhistle, in the extreme west; Hareshaw, near the Plashetts Coalfield, on the North Tyne, where argillaceous iron ore and clay ores are found, of nearly as good a quality as that of Staffordshire,* and Port Seaham, Felling, and Washington, in the south. As a greater weight of coal is required for reducing a given weight of ironstone, it is not too much to suppose that, with good rail and river accommodation, ores of different qualities will be brought to the coal on the Tyne for the sake of economy—the smaller weight to the larger. Nor is the expectation too sanguine that the raw clay ironstone trade from great distances, by sea and river craft, and by rail, will find its principal location in the neighbourhood of the Tyne, in consequence of it being found cheapest to concentrate it at a point where there is a noble river answering every purpose of importation, exportation, and local transit. The coal used in supplying the Cleveland districts is taken twenty-five or thirty miles by railway, while, on the borders of the Tyne, there is a large working population, and labour is consequently cheap and more accessible; at the same time, there is a large plant in existence, and therefore much less capital is required to establish furnaces, &c., than is the case in a desolate country like Cleveland. Moreover, limestone can be obtained on the Tyne, in close proximity to the furnaces, and which, with good rail and river transit to that cheap highway the sea, can be carried a great distance at little expense. The Cleveland clay ironstone requires, for the manufacture of superior pig metal, the admixture of richer and better qualities—the hematite ore, and

* Seventy of these furnaces are in full operation, and thirty-seven are also nearly ready for work, and when the whole are fully employed, they will consume nearly double the quantity of coal at present required, or 4,000,000 tons.

the well-known clay ironstone of the Midland district. The former is brought all the way from Egremont and Whitehaven, in Cumberland, to Middlesbro', at much expense; but, on the Tyne, it can be obtained much more easily and cheaply. It has been proved, that in twenty minutes a ship can load at a point on the coast called Staithes, twelve miles south of Redcar, with argillaceous lias ore, and be in the Tyne in four hours, returning to London and elsewhere with proportionate celerity.

If adequate facilities were afforded, a larger trade in coal and iron should be carried on from the Tyne with France and America. Until the conclusion of Mr. Cobden's treaty, the French Government levied a duty of 3s. a ton upon English coal, equal to one-half of the price at which we of the Northern Coal-field can put it on board ship, while Belgian coal was paying only 1s. 6d. per ton. In both cases this duty was additional to the Paris octroi of 6s. 8d. per ton. But, under the commercial treaty, the 3s., also 1s. 6d., duty upon each has been reduced to one-half, and indeed there appears every disposition on the part of the Emperor and his Ministers to encourage the British coal trade. With respect to America, it is a remarkable fact, that at the present time we are sending coals from the Tyne to New York and other American ports, at the extremely low freight of 10s. per ton, and small quantities have gone from London at 9s. per ton. It is well known that the Americans find certain descriptions of our coal to be of a much better quality than their own, and if these coals can be put on board in the Tyne at from 4s. 6d. to 5s. 6d. a ton, and carried across the Atlantic at as low freights as 10s. a ton, costing, therefore, only about 15s. per ton on the average, the Americans will undoubtedly become good customers of ours. It will be found, too, that northern coal is as cheap as the coal from the west coast, for although freights are lower at Liverpool and contiguous ports, yet the price of the coal is higher, and the article itself is not so suitable. The Americans find that it answers their purpose for the gas and iron manufactures, and sundry other trades, to import our superior produce into their seaport towns, and the difference of quality is all in their favour. Of course none but the largest vessels can afford to carry coals at that low figure, except as back carriage, in the same manner that lead and other ores are brought from Spain to the Tyne. It is accommodation for these large vessels that is so much needed, and which Mr. Ure's plan is calculated to supply.

It may be observed, too, that there are numerous branches of industry that depend greatly upon the coal and iron trades, which, if the proposed improvements are carried out, will find the Tyne more advantageous, and better calculated to promote their development and success, than

any other of the rivers, ports, docks, and harbours to which we have alluded. The Tyne will then be able, not only to hold its own, but to attract new branches of industry to its banks, and thus to increase its revenue year by year, and promote the prosperity of the staple trade of the district.

The total area of coal measures in the Great Northern Field is 800 square miles, and would originally contain 8,200,000,000 tons of coal, as follows:—

TABLE, No. 1.

Quantity of Coal in the Entire Field.

	Sq. Miles.	Total.	Probable quantity shipped and for shipment in the Tyne.	Other Ports.
		Tons	Tons.	Tons.
A (yellow)	21	260,000,000	250,000,000	10,000,000
B (yellow)	23	320,000,000	300,000,000	20,000,000
C (yellow)	93			
Tons. 706,000,000 / Undersea 140,776,008		846,776,008	646,776,008	200,000,000
Steam Coal District—Total ..		1,426,776,008	1,196,776,008	230,000,000
D (red)	162	1,200,000,000	1,200,000,000	....
Total in Northumberland ..		2,626,776,008	2,396,776,008	230,000,000
E (green)	162	1,157,029,749	1,060,000,000	97,029,749
F (brown)	152	2,200,000,000	800,000,000	1,400,000,000
G (black)	152	2,200,000,000	800,000,000	1,400,000,000
Total in Durham		5,557,029,749	2,660,776,008	2,897,029,749
Durham and Northumberland Total		8,183,805,757	5,056,776,008	3,127,000,749

From this, deduct the quantity estimated by the writer to have been excavated up to the year 1854, viz., 3,060,916,801 tons from the two counties, and the quantity excavated between 1854 and 1860 at the rate of 17,000,000 tons yearly, viz., 85,000,000 tons, and we find a total quantity remaining of 5,026,998,957 tons. Divide this amount by the present yearly production, 22,500,000 tons, and the result is 223—the number of years that the field will last at the present rate of working.

Some fifteen years ago, Mr. Greenwell, in estimating the duration of the Northern Coal-field, observed that if the production of saleable coal reached 10,000,000 tons yearly, the coal beds would last for 331 years. The writer of this paper, in 1854, showed that the annual yield was

14,000,000 tons, and he estimated the duration at 365 years, but predicted that, in a very short time, 20,000,000 tons would be raised per year, in which case the field would be exhausted in 256 years. At the present date, even this quantity has been exceeded by 2,500,000 tons, and the duration of the northern coal seams is, therefore, as shown in the preceding statement, reduced to 223 years.

The 22,500,000 tons raised in this district are, in the writer's estimation, distributed in the following proportions :—

TABLE No. 2.

	Tons.	Tons.
Shipments oversea and coastwise - - -	10,583,118	
Led and consumed by vessels on the rivers Tyne and Wear, say for local trade - -	1,113,000	
		11,696,118
Consumed in iron furnaces - - - -	2,000,000	
Factory and household consumption (local) -	4,800,000	
Colliery consumption and waste underground, about - - - - - - - -	4,000,000	
		10,800,000
Total Great Northern Coal-field - -		22,496,118

Now, as has been already noticed, the oversea exportation from the Great Northern Coal-field is rapidly increasing, so that, in a short period, we may expect to see it fully 2,000,000 tons per annum in excess of the present quantity. The blowing in of all the dormant furnaces in this district would most probably create a demand for an extra 2,000,000 tons; and it is not improbable that the local manufacturers in this district may go on increasing their consumption, and that 2,000,000 tons per annum extra may be put down to their account. This would raise the extraction to 28,500,000 tons yearly, and thus lessen the duration of the coal-field to 177 years.* This may be thought by many persons to be an exaggerated estimate of the future progress of coal production, yet, if we look back only six or seven years, we see precisely the same augmentation taking place; and with all the appliances and transit facilities that have been brought into play within the last thirty years, who shall venture to place a limit upon our power of production, so long as coal remains to be won, and its use is as indispensable as it is at the present day?

* In these and all other estimates no account has been taken of a practice which prevails rather extensively in the trade, namely, that of giving overweight. The Newcastle chaldron is fifty-three cwts., but many collieries give fifty-five cwts. and more to the chaldron, which surplus does not enter into the returns of the total production. In a large quantity this overweight becomes a considerable item, and renders the excavation of coal—past and future—greater than it would otherwise appear to be. Indeed, if the practice continue, it may happen that the total duration of the coal-field may be taken at eight or ten years less than we have previously allowed, making the exhaustion of the coal-seams complete in 167 years.

TABLE, No. 3.

Comparative Statement of the Shipments of Coal from the Great Northern Coal-field, showing the Shipments in the Docks, and the Quantity led by River Craft and consumed by Steamers and Manufactories on the Tyne and Wear.

			Tons.
Shipped from the Tyne, at drops and staiths			1,317,820
Do. from the Northumberland Docks	1,689,037		
Do. from the Tyne Docks	1,421,674		
			3,110,711
Do. from the West Coast			68,987
Estimated quantity sent to Hull, Selby, and other southern ports, per rail and ship			100,000
Estimated to be carried by sundry river craft, and consumed at manufactories and by steamboats, &c., on the Tyne			1,000,000
			5,597,518

There are in the Tyne 200 tug steamboats, besides passenger boats, and about 250 other craft engaged in carrying coals.

			Tons.
Shipped in the Wear, from Sunderland, at drops, &c.,			1,387,010
Do. from the North Dock	99,000		
Do. from the South Dock	1,300,000		
			1,399,000
Estimated to be carried by river craft, and consumed by steamers, manufactories, &c., on the Wear			113,000
			2,899,010

The above figures show that the aggregate coal trade of the Tyne is about double that of Sunderland, while the local coal traffic (by river craft, &c.) is greater by tenfold. The shipments from the remaining ports, harbours, and rivers on the east coast are as follow:—

	Tons.	
From West Hartlepool	961,102	
Do. Old Hartlepool	940,322	
Do. Port Seaham	641,322	
Do. Middlesbro'-on-Tees	354,204	
Do. Blyth, Seaton Sluice, &c.	224,451	
Do. Warkworth Harbour	77,977	
Do. the Wansbeck	50	
Do. Berwick	162	
		3,199,590
Total led by ships, steamers, and river craft from the Great Northern Coalfield, in the year 1860		11,696,118
Leaving, for local consumption, about		10,800,000
Total		22,496,118

TABLE, No. 4.

Shipments of Coal from the Great Northern Coal-field, showing the comparative quantities Coastwise and Foreign, and also those used and led by River Craft in the Tyne, the Wear, and other places.

Ports.	Coastwise.	Foreign.	Total by Sea.	Local.	Total.
Newcastle and Shields, on river Tyne	2,132,621	2,275,910	4,498,531		
Ditto, by river craft	...	...	1,000,000		
Port Carlisle and Silloth Bay (west coast)	42,157	....	42,257		
Maryport (do)	26,730	....	26,730		
Hull, Selby, and other southern ports, estimated	....	100,000	100,000		
Total from the Tyne	2,221,608	2,375,910	5,597,518		
Sunderland	1,812,716	973,294	2,786,010		
Ditto, by river craft	....	....	113,000		
Total from the Wear	1,812,716	973,294	2,899,010		
West Hartlepool	1,322,106	579,318	960,102		
Old Hartlepool			941,322		
Seaham	602,632	38,690	641,322		
Tees, Middlesbro'	217,704	136,500	354,204		
Warkworth	8,744	69,233	77,977		
Blyth and Seaton Sluice	109,428	115,023	224,451		
Wansbeck	50	....	50		
Berwick	162	....	162		
Total	2,260,826	938,764	3,199,590	10,800,000	22,496,118

Abstract of the above Table.

Ports.	Coastwise.	Foreign.	Otherwise at Ports & Rivers.	Total.
Tyne	2,221,608	2,375,910	1,168,987	5,597,518
Wear	1,812,716	973,294	113,000	2,899,010
Hartlepool, Tees, Seaham, Blyth, Warkworth, Wansbeck, Berwick	2,260,826	938,764	....	3,199,590
	6,295,150	4,287,968	1,281,987	11,696,118
Local, about	....	....	....	10,800,000
Total from Northumberland and Durham, or Great Northern Coal field,				22,496,118

The following Table gives the Depth of Water in the Rivers and Harbours on the North-east Coast, at average Spring Tides.

The undermentioned figures have been obtained from official sources, and can therefore be relied upon as accurate.

	Average Spring Tides. Feet.	Average Spring Tides when improved by Mr. Ure.
The Tyne, at Tynemouth Bar	20½ ..	29
„ Tyne Docks	24 ..	29
„ Northumberland Docks	21 ..	29
„ Newcastle and Gateshead	17* ..	23
„ Blaydon	8* ..	23
Proposed dock at J, between Lemington, Blaydon, and Stella	18½ ..	23
Do. Tynemouth, Proposed Low Lights Dock, near the Bar, entrance 100 feet wide	— ..	26
The Wear, at Sunderland Bar, say	18½ ..	—
„ North Dock (ordinary tides)	20½ ..	—
„ South Dock, (ordinary tides)	22½ ..	—
„ Lambton, Victoria Bridge	5½ ..	5½
Seaham	16 ..	—
West Hartlepool	20½ ..	—
Old Hartlepool	19½ ..	—
Tees, Middlesbro' Dock	18½ ..	—
Blyth Harbour	15 ..	—
Seaton Sluice	13 ..	—
Wansbeck	11 ..	—
Warkworth, on the Bar	16½ ..	—
Redcar Sea Coast, space between projecting rocks, 40 feet deep, over 350 acres, at high water, which are dry at low tide	— ..	—
Staithes, twelve miles south of Redcar, for shipment of ironstone, say	13 ..	—

* At Newcastle quay and at Blaydon the water in the bed of the river is three and eleven feet respectively deeper than the figures indicate. But below both points are shoals which impede the navigation, and a higher figure would be calculated to mislead. These shoals, however, when Mr. Ure's improvements are carried out, will be swept away.

TABLE, No. 5.

The following Table is an Abstract of the Coal Shipments and Local Trade in the undermentioned Districts showing the preponderance of the Shipments from the Great Northern Coal-field over those of other Districts.

	Total.	Shipments.	Local.	Total Shipments.	Total Local.	Grand Total.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Durham and Northumberland	22,496,118	11,696,118	10,800,000	11,696,118	10,800,000	22,496,118
South Wales and Monmouthshire	6,254,813	3,958,435	2,296,378			
North Wales	1,750,500	....	1,750,500			
Scotland	10,900,000	1,397,246	9,502,754			
Ireland	119,425	2,628	116,797			
	19,024,738	5,358,309	13,666,429	5,358,309	13,666,429	19,024,738
Cumberland	1,171,052	723,641	447,411			
Yorkshire	9,284,000	379,081	13,844,919			
Derbyshire and Nottinghamshire	4,940,000					
Leicestershire	730,000	....	730,000			
Warwickshire	545,000	....	545,000			
Gloucestershire, Somersetshire, Devonshire	5,503,400	174,968	5,328,432			
	22,173,452	1,277,690	20,895,762	1,277,690	20,895,762	22,173,452
Staffordshire, Worcestershire	7,648,300	....	7,648,300			
Lancashire	11,350,000	962,822	11,137,678			
Cheshire	750,500					
Shropshire	850,500	....	850,500			
	20,599,300	962,822	19,636,478	962,822	19,636,478	20,599,300
				19,294,939	64,998,669	84,293,608

The Tables which follow show these Statistics in detail.

TABLE, No. 6.

Produce and Shipments from the Great Northern Coal-field brought forward.

Ports from which Shipped.	Coastwise.	Foreign.	Total by Sea and River Craft.	Local.	Total Production.
	Tons.	Tons.	Tons.	Tons.	Tons.
Durham and Northumberland - -	6,226,163	5,469,955	11,696,118	10,800,000	22,496,118

Since December, 1855, when the writer last wrote on the subject, the produce of this coal-field has increased about fifty per cent. In all other parts of the kingdom the increase has been only thirty per cent.

TABLE, No. 7.

Produce of the North and South Wales Coal-field in 1860, showing the Quantity Exported and used Locally.

Ports from which Shipped.	Coastwise.	Foreign.	Total by Sea.	Total by Local Trade in Wales.	Grand Total.
	Tons.	Tons.	Tons.	Tons.	Tons.
Cardiff - - -	782,002	1,133,086	1,915,073		
Newport - -	629,206	187,591	816,797		
Swansea - - -	227,675	295,102	522,777		
Neath - - -	185,310	13,740	199,050		
Port Talbot - -	61,965	....	61,965		
Porth Cawl - -	17,196	....	17,196		
Llanelly - - -	284,170	89,996	374,166		
Milford - - -	51,351	45	51,396		
Local - - -	....	....	....	2,296,378	6,254,813
NORTH WALES.					
Flintshire - 590,500	....	....	....	....	....
Anglesea - 20,500	....	....	....	....	....
Denbighshire 1,139,500	....	....	....	1,750,500	1,750,500
Total - -	2,238,875	1,719,560	3,958,435	4,046,878	8,005,313

TABLE, No. 8.

Produce and Shipments of Coal in Scotland in 1860.

Ports from which Shipped.	Coastwise.	Foreign.	Total by Sea.	Local.	Total.
	Tons.	Tons.	Tons.	Tons.	Tons.
Borrowstoness -	124,354	151,973	276,327		
Leith - - -	6,696	35,593	42,259		
Grangemouth -	1,799	61,409	213,382		
Alloa - - -	13,750	59,217	72,967		
Kirkaldy - -	43,828	73,769	117,597		
Dundee - - -	934	28,786	29,720		
Aberdeen - -	....	222	222		
Peterhead - - -	....	90	90		
Greenock - -	14,700	49,105	63,805		
Port Glasgow - -	50	6,001	6,051		
Glasgow - -	104,931	55,058	109,989		
Irvine and Troon -	367,319	129,799	497,118		
Ayr and Girvan -	65,453	1,410	66,863		
Total - - -	743,814	653,432	1,397,246	9,502,754	10,900,000

TABLE, No. 9.

Produce and Shipments of Coal in Ireland in 1860.

Ports from which Shipped.	Coastwise.	Foreign.	Total by Sea.	Local.	Total.
	Tons	Tons.	Tons.	Tons.	Tons.
Dublin - - -	....	432	432		
Wrexford - -	....	200	200		
Waterford - -	....	148	148		
Ross - - -	105	127	232		
Cork - - -	....	469	469		
Tralee - - -	....	60	60		
Londonderry - -	....	394	394		
Belfast - - -	....	693	693		
Total - - -	105	2523	2628	116,797	119,425

TABLE, No. 10.

Produce and Shipments of Coal in Cumberland in 1860.

Ports from which Shipped.	Coastwise.	Foreign.	Total by Sea.	Local.	Total.
	Tons.	Tons.	Tons.	Tons.	Tons.
Whitehaven - -	191,679	3,441	194,520		
Workington - -	134,339	1,964	136,303		
Maryport - - -	386,372	6,446	392,818		
Total - -	711,790	11,851	723,641	447,411	1,171,052

TABLE, No. 11.

Produce and Shipments of Coal in Lancashire, Cheshire, Shropshire, Staffordshire, and Worcestershire in 1860.

Ports from which Shipped.	Coastwise.	Foreign.	Total by Sea.	Local.	Total.
	Tons.	Tons.	Tons.	Tons.	Tons.
Chester - - -	56,838	200	57,038		
Liverpool - -	234,701	595,639	830,340		
Preston - - -	40,031	822	41,753		
Fleetwood - -	23,652	4,366	28,018		
Lancaster - - -	2,532	2,225	4,757		
Runcorn - -	....	916	916		
Total - -	358,654	604,268	962,822	19,635,978	20,598,800

TABLE, No. 12.

Produce and Shipments of Coal in Gloucestershire, Somersetshire, Devonshire, Warwickshire, and Leicestershire in 1860.

Ports from which Shipped.	Coastwise.	Foreign.	Total by Sea.	Local.	Total.
	Tons.	Tons.	Tons.	Tons.	Tons.
Bristol - - -	674	10,223	10,897		
Gloucester - -	158,301	6,355	82		
Chepstow - - -	....	89	....		
Gloucestershire, Somersetshire, & Devonshire - -	158,301	16,677	174,968	5,328,432	5,503,400
Warwickshire - -	....	....	....	545,000	545,000
Leicestershire, -	....	....	....	730,000	730,000
Total - -	158,301	16,677	174,968	6,603,432	6,778,400

TABLE, No. 13.

Produce and Shipments of Coal in Yorkshire, Derbyshire, and Nottinghamshire in 1860.

Ports from which Shipped.	Coastwise.	Foreign.	Total by Sea.	Local.	Total.
	Tons.	Tons.	Tons.	Tons.	Tons.
Gainsborough - -	17,948	....	17,945		
Hull - - -	10,149	159,261	169,410		
Goole - - -	95,776	15,452	111,228		
Grimsby - -	9,555	70,943	80,498		
Total - -	....	....	379,081	13,844,919	14,224,000

From Selby and several other ports small shipments are made, which are included in the total. *Vide* preceding tables Nos. 3, 4, and 5.

After the foregoing pages had been read at Birmingham, Mr. Robert Hunt, F.R.S., the Keeper of the Mining Records, favoured me with an early proof of his Mineral Statistics, from which the following tables are derived:—

Coal Shipments, Foreign and Coastwise, in 1859 *and* 1860.

Coastwise.	1859.	1860.	Total 1860.
	Tons.	Tons.	Tons.
Coals - - - - -	9,913,595	10,522,126	
Coke - - - - -	45,991	40,203	
Anthracite - - - -	148,247	158,387	
Patent Fuel - - -	29,190	26,197	
Total - - -	10,137,023	10,746,213	10,746,913

Foreign.	1859.	1860.	Total 1860.
	Tons.	Tons.	Tons.
Coals - - - - -	6,784,337	7,060,388	
Coke - - - - -	213,579	247,761	
Anthracite - - - -	9,033	13,683	
Patent Fuel - - -	75,000	90,743	
Total Foreign - -	7,081,949	7,412,575	7,412,575
		Coastwise - -	10,746,913
		Total -	18,289,488

Patent Fuel sent from the undermentioned Ports Coastwise to other Ports in the United Kingdom, also Foreign.

Ports from which Shipped.	Coastwise.	Foreign.	Value.
	Tons.	Tons.	£.
Cardiff	1,245	7,567	4,868
Swansea	21,708	38,824	37,766
Llanelly	190	255	134
Chester	1,594	....	....
Newcastle	1,370	755	484
Total Coastwise	26,197		
Exported from London		6,104	6,828
„ Bristol		697	504
„ Liverpool		5,359	3,916
„ Shields		1,000	756
„ Penzance		200	100
		90,761	£55,356
Ardrossan, apparently omitted by Hunt		50	
		90,811	

The above value does not include the Coastwise Coal and Coke, only that which is exported Foreign.

Coal sent from Ports distant from Coal-field in 1860.

Ports from which Shipped.	Coastwise.	Foreign.	Total.
	Tons.	Tons.	Tons.
London	2,163	61,590	
Rochester	3,404	....	
Portsmouth	9,588	....	
Weymouth	345	12	
Plymouth	9	3	
Faversham	82	....	
Boston	110	954	
Penzance	....	110	
Ramsgate	....	190	
Scilly	....	281	
Southampton	....	145	
Poole	....	150	
Dartmouth	....	2	
Gainsborough	....	3,023	
Lowestoft	....	544	
Harwich	....	215	
Total	15,701	67,219	82,920

Coals brought by Railway and by Sea within the London District.

By Railway.		Tons.	Cwts.
London and North-Western Railway		698,418	16
Great Northern	do.	502,813	14
Eastern Counties	do.	121,225	16
Great Western	do.	63,944	0
Midland	do.	58,490	0
South-Western	do.	17,589	3
South-Eastern	do.	14,585	19
Hertford, Luton, &c.	do.	4,416	19
London and Tilbury, &c.	do.	958	0
London and Brighton	do.	104	0
	Total	1,477,545	16

By Sea.		Tons.	Cwts.
From Newcastle		1,347,574	0
„ Seaham		210,418	0
„ Sunderland		977,519	0
„ Middlesbro'		61,183	0
„ Hartlepool and West Hartlepool		703,836	0
„ Blyth		40,986	0
„ Scotland		13,002	0
„ Wales		130,009	0
„ Yorkshire and Midland Counties		45,230	0
Small Coal		25,047	0
Coke		16,671	0
Culm		1,902	0
Total by Sea		3,573,377	0
Total by Railway		1,447,545	16
Total by Canal, &c.,		52,353	0
Total		5,073,275	16

DISCUSSION

ON

MR. HALL'S PAPER ON THE RIVERS, PORTS, AND HARBOURS OF THE NORTHERN COAL-FIELD.

The PRESIDENT said—I think, gentlemen, that the statistical account which Mr. Hall has given us of the Northern Coal Districts is most valuable, but I think the statement about the depth of water at Redcar requires some explanation.

Mr. T. Y. HALL—I believe it is about forty-four feet at high water.

The PRESIDENT—There is no dock at Redcar, and it must not go forth to the public that there is a dock there with a depth of water at high tide of forty-four feet.

Mr. T. Y. HALL—There is something like a natural dock or harbour there, about 350 acres in extent, the average depth of water being about forty feet. This 350 acres lies between two rocks, which project into the sea, and are exposed at low tides.

The PRESIDENT—Still there is no dock whatever at Redcar at present; that is what I wish to have explained.

Mr. T. Y. HALL—No; it is sea coast; there is no dock.

Mr. WM. MATHEWS—I have, with the permission of the President, to move that the thanks of this meeting be given to Mr. Thomas Young Hall, for his very interesting paper, which is most valuable as a contribution to the statistics of the state of the coal trade of the northern districts. For myself, I am free to confess that I am too little acquainted with the character of the district to be in a position to criticise the paper we have just heard read, although it may be open to criticism. There are, however, gentlemen present who are more intimately acquainted with that district, and I do hope that some observations will be offered on Mr. Hall's paper, which admits of discussion, in reference to some of our most

important interests. There is one point which I think it is most desirable to impress on this meeting, and that is, that the northern district is not only very important in reference to its ordinary mercantile position with respect to the coal trade of the whole world, but it is of the greatest possible importance with respect to South Staffordshire in particular. The supply of coal in the South Staffordshire district has seriously fallen off of late years, and has become quite inadequate to meet the demand occasioned by the development of its other manufacturing resources. We are, therefore, obliged to lean somewhat on the aids which the produce of the Northern Coal-field opens up to us, and if, by any chance, the resources we now enjoy from that and other districts in England should be withheld, we should feel the inconvenience of being deprived of such resources very sensibly indeed. I will not venture to intrude on the meeting any observations with respect to the details of Mr. Hall's paper, but I do trust that some of the gentlemen who are now present from the northern district will enter upon a discussion of some of the more prominent points which Mr. Hall has so ably brought before the meeting.

Mr. POTTER—I think Mr. Hall's paper has brought the details of this important question out in a very satisfactory manner, and I quite concur with him as to the advisability of bringing out the coal traffic as much as possible in the direction of the Tyne. That would not only be of great advantage to the owners of collieries in that immediate district, but also to others, for this simple reason, that it would produce a higher rate than elsewhere. On this point I think the paper has spoken very freely and plainly.

The PRESIDENT—This paper is very valuable in one point of view, which has been referred to in the observations of Mr. Mathews. I mean with reference to the bearing and influence which the northern coal and ironstone districts must exercise on the South Staffordshire ironstone district, and the future development of that trade. The whole history of the trade of the northern ironstone is, indeed, most curious and interesting. There can be no doubt whatever that there has been a most extraordinary development of the ironstone of the Cleveland district, mainly in consequence of its connection with the coal-field of Durham. I believe that the consumption of coal now used in connection with the ironworks of that district amounts to something like 3,000,000 tons annually. Whether or not, the quality of the iron which is made from the ironstone of the Cleveland district alone is such as will

enable it to compete with the Staffordshire iron, and if so, to what extent such competition will extend, I am at present quite unable to say, more especially as I am not at this moment sufficiently well informed as to the relative cost of making the two descriptions of iron. There is certainly ample room for a very useful and interesting inquiry into the relative qualities and cost of production of iron in each of the districts, for the purpose of forming some data that may guide us in ascertaining what will be the probable effect in South Staffordshire, of the development of the iron trade in the Cleveland district, and whether the superior quality of the iron manufactured in South Staffordshire will enable it to counteract the effect of the competition of the cheaper manufacture of the Cleveland iron. I rather suppose, and I fancy it will so turn out, that there is room enough in the different markets for both of them, especially with reference to the different qualities and comparative cost of production of the two qualities of iron. I have followed, as carefully as I could, the statistics relating to the different districts which have been quoted by Mr. Hall, and, generally speaking, I think they are accurate. Of course, as far as it relates to the distribution of our local trade, with reference to the ports at which it may be shipped, there is much that is speculative in the paper. The improvement of the Tyne is now in progress, but as to the effect which such improvements will have on the local coal trade, it must, of course, be a matter of subsequent experience. It is a somewhat intricate speculation as to what quantity of coal will be shipped from Sunderland, and what from the Tyne and other ports: that depends, to a great extent, upon what ports are the cheapest to ship at, in connection with the distances from the different collieries, and with reference to tolls, dues, facilities of shipping, and other circumstances.

Mr. GREENWELL—I see a line drawn on the map as representing the southern boundary of the coal-field. I wish to ask Mr. Hall if he has laid down that line from any actual observation—whether it is supposed that that is the outcrop of the southern portion of the coal measures to the surface, or whether it is represented on the map rather as the commercial than the geological boundary; and if, in point of fact, the coal is not supposed only to have dipped down beneath the magnesian limestone and the red sandstone?

Mr. HALL—The reason why I conclude this line to be the southern boundary of the coal-field is simply this,—that, although pits have been sunk at enormous expense south of that line on the map, the result has been always the same, no profitably workable coal having been found.

I believe that the total cost of the pits that have been sunk south of that line amounts to upwards of £300,000. There have been pits sunk all along the line south, and the result has always been the same. [Mr. Hall explained on the map the different positions in which pits had been sunk south of the line, which he had marked on the map as the southern boundary of the coal-field.] The fault or stoppage seems to wind round by Garmondsway, Ferryhill, and Auckland, to Cockfield Fell, north of Raby Castle.

Mr. GREENWELL—I suppose, that if asked to give a professional opinion on the subject, you would prefer to call it the commercial rather than the geological outcrop?

Mr. HALL—Well, at Castle Eden pit it is a geological "crop-out," or cessation, for the coal runs up against limestone, and we see no more of it. If that limestone be the magnesian, it is about 240 feet lower down than one would expect to find it. Half a mile from this point the limestone itself crops out at the surface.

MR. WOODHOUSE—It appears evident to me, from the statement of Mr. Greenwell, that he is able to explain some of the causes of the failure of the coal in this direction, and if any sections could be supplied, it would be exceedingly useful to geologists to ascertain whether the coal ends there, being stopped abruptly by a dyke; or whether after crossing the dyke which exists at the boundary line indicated on the plan, it extends still further to the south and south-east. I apprehend sections of those strata on the south side of the boundary line have been preserved, and could probably be produced; they would, I am sure, be found to be very useful. There is a similar occurrence in the county with which I am connected. I know a colliery which is supposed to be on the very edge of the South Staffordshire coal-field, and where the coal comes right up to the new red sandstone. It is, however, a question of doubt in my mind whether or not the coal extends under that formation, and even in the direction of Birmingham. The colliery to which I have referred is situate in the neighbourhood of West Bromwich. I cannot help looking at this as a parallel case, and it would be exceedingly interesting if sections could be produced, and if we could induce Mr. Greenwell to give us a paper on this subject, for I am quite certain that the information would be very valuable.

Mr. HALL—This (explaining by the plan) is the outburst of the magnesian limestone; the red sandstone is superimposed, running in the same direction; and above the red sandstone is the lias.

Mr. W. Williams—Is not that simply the boundary line of the coal as far as it has been worked? Taking a line along the country there where the mines have been worked, after proceeding fifty or sixty miles into Yorkshire, you might get again into the same measures. It appears to me that it is the outside of the field as far as it has been worked.

The President—It will be seen by the map, that the magnesian limestone after running in a nearly parallel line to the coast from Sunderland, trends away south-west to Ferry Hill, from whence the outcrop or escarpment runs more south. Limiting the observations to the eastern and southern limits of the coal field, below the magnesian limestone and superincumbent red sandstone, it must be observed, that the coal-field of Durham is in the shape of an elongated basin, the deepest point running into the sea in a south-east line at or near Sunderland. To the north of that line the coal rises into the sea; we have not yet ascertained the point or line of deepest depression from Sunderland southwards to Seaham, but, following the line of the coast, we know that the coal at Castle Eden, Wingate Grange, and South Wingate, rises southward, and that the Five-Quarter and Main Coal beds rise into, and are cut off southward by the magnesian limestone; and this is the case from those localities westward. All along the southern edge of the coal beds, they rise into and are cut off by the magnesian limestone, until they reach the escarpment of the limestone, when the outcrop of the coal beds pass into the alluvial soil, or, as it is termed, "crop out to the surface." The edge or boundary line of the coal-field on the map, from Castle Eden westward to Ferry Hill, shows where the upper beds of coal have been cut off, or where they have run up into the limestone, and so terminated. But it has not yet been proved how that affects the deeper beds. The deeper beds of coal may extend farther south, underneath the magnesian limestone, to what extent is not yet ascertained. Then, farther west from Ferryhill, the crop of the limestone trends away to the south, and the coal crops out at the surface. With regard to the southern boundary of the coal-field south from Bishop Auckland and Shildon, it has not yet been ascertained to what distance beyond the line laid down on the map, the coal-beds extend. There has been recently opened out lower beds of coal, and these lower beds extend very much beyond the limits of the break shown on the map, and alluded to by Mr. Hall. Reverting back to the eastern part of the map, how far the coal measures extend to the south-east beyond that line we do not know; it has not been yet ascertained. As I said before, the coal strata dips underneath

the magnesian limestone from Sunderland southwards along the line of the coast. The magnesian limestone continues until we approach the Tees, when the red sandstone comes in, resting on the limestone, and then we have the lias and ironstone deposits. A gentleman present, Mr. Marley, whose valuable paper on the Cleveland district I have already noticed, stated in that paper that the coal measures might, after rising up into the limestone, again dip under the limestone and red sandstone, and so to be found at the mouth of the Tees. I took the liberty of expressing an opinion adverse to that, in the discussion of that paper. You will find the whole of the proceedings in the volumes of the Institute, with a very extensive set of maps in illustration of the geology of that district. Mr. Marley shows the coal, in one of the maps, as dipping underneath the magnesian limestone and the red sandstone, and again rising southwards, in the vicinity of the Tees. I am of opinion that it does not do so, but that, when once the edge of the basin of the coal measures rises into the oolitic series, there is an end of it; but I should be glad to hear any expression of opinion from Mr. Marley on the subject, and I trust that he will give us some explanation of his views on this occasion.

Mr. MARLEY—All that my friend Mr. Greenwell and myself wished to ascertain from Mr. Hall was, whether the line laid down on the map was to be taken as the southern geological outcrop of the coal-field of Durham, or whether it was merely the southern commercial boundary; because, if it is merely the commercial boundary, the line laid down on the plan as the southern outcrop might tend to mislead with respect to any future trials for coal. It is quite true that several trials for coal have been made along that boundary line, and some seams of coal have been bored to on the south of that line, although hitherto the trials have been commercial failures. If, therefore, it is put down as the commercial boundary, it may be taken as correct. With respect to the remarks which were made by the President with reference to the continuation of the coal-field towards and south of Middlesbro' and the Tees, and the allusion he made to my paper on the Cleveland Ironstone, coupled with the probability of the continuation of the coal-field in that direction, all I contended then, and which I still think I have a right to contend, is, that there is not any geological fact whatever ascertained which tends to prove conclusively that the coal-field does not extend in a southerly direction, and until such facts are ascertained, we have a right to assume, inasmuch as there is no *prima facie* evidence against it, that it may exist. With respect to the upper seams of coal cropping out

against the limestone, it has never yet, I believe, been shown conclusively that they come right against the limestone. In one case, the top seam comes against the new red sandstone which lies underneath the limestone; and what the President said with respect to the outcrop of the coal measures up to the limestone and red sandstone being the terminus of the coal beds, it seems to me that, instead of its being a simple outcrop, it is a large dip dyke, and so abutting against the red sandstone. I think it is probable that the coal-field may be continued farther towards the south, and that the supposed terminus is a dip dyke, instead of an outcrop of the lower strata of coal. It has not yet been proved that the coal does not there *lie below the strata of lias*, and its associates, and come out again south of the boundary line marked on the map. With the President, I should rather contend that, until it has been positively proved as a geological fact that the coal-field is not continued south of that line, it is possible and probable to prove that coal does exist in that direction.

Mr. GREENWELL—In confirmation of the view which has been taken by Mr. Marley, I may refer to the Red Rock fault at Poynton, in Cheshire, where a stone drift from the coal goes across the fault, the opposite side of it being red sandstone, although the drift is 200 yards below the surface. On the one side is the coal, and on the other the new red sandstone. It is in the Durham case more in the shape of this great dyke than that of a simple outcrop.

Mr. W. WILLIAMS—For the information of those who are present, I will state what has occurred within my own knowledge, and which will go very far to show that none of us know very accurately the limits of the coal-field. I am not a very old man; but since I left school I can remember land in this neighbourhood which was almost given away—sold at £60 an acre freehold—because it was currently believed that there were no coal mines under it. About fifty years ago my father purchased property near Tipton and West Bromwich, and he was informed by Mr. Holland, who was always held to be one of the first mining engineers in the neighbourhood, that the property in the vicinity of West Bromwich would never be worth working as coal mines; that even if there were coal under it, it would never pay the cost of getting, but that he did not think there was any. Even as recently as twenty years ago another celebrated mining engineer in that district positively asserted that there was no coal in that neighbourhood, and that, sink as deep as we might, nothing but expense would result. I know that there have been several instances of

the magnesian limestone from Sunderland south- . . I have
the coast. The magnesian limestone continu- -- places
Tees, when the red sandstone comes in, resting . . was at one
we have the lias and ironstone depo- . -stone, as coal-
Mr. Marley, whose valuable paper on the . . -ined, I am
noticed, stated in that paper that the c- . . the beds may
into the limestone, again dip under . . .
so to be found at the mouth of th- . . -nd that this coal-
an opinion adverse to that, in t- . . -ne marked on the
the whole of the proceedings . . -y fairly when he says,
extensive set of maps in . . measures do not extend
Mr. Marley shows the c- . . -ed in a geological point
the magnesian limesto- . . that they may do so. I
wards, in the vicini- . . speculations which have
so, but that, wh- . . extent of the coal-fields
into the oolit- . . the facts which have since
any expres- . . existence of coal in the various
that he w- . . results as to the extent of
Mr. V- . . within even a comparatively
to as- . . -nce and workable quality of coal
wa- . . now speaking, at one time it was
D- . . late Mr. Winch and Mr. Buddle,
. . that there was no coal of commer-
. . opinion there was no coal at all,
. . The magnesian limestone, as will
. . large extent of approachable coal
. . millions of tons of coal now being
. . comprising the Hetton, Newbottle, South
. . Shotton, and other collieries. It only
. . -ctions which have been indulged in with
. . coal-field. In the consideration of this
. . -ed to notice that the Durham Coal-field is
. . the unconformable magnesian limestone,
. . -rian resting upon the eastern and southern
. . although we know that the superimposed
. . have nothing whatever to do with the existence,
. . coal measures, as we see in some localities all
. . -ks, even up to the tertiary deposits, resting on the
. . this case their position is not without interest.

the south, west, north, and part of the east sides of the coal the basin complete, either rising out to the surface, or upwards superimposed beds of magnesian limestone; except a small portion of the south-eastern extremity, in the line of the deepest part or trough of the basin, which the interposition of the sea has prevented from being explored, and it is only in that restricted and comparatively small portion of the circle of the edges of the basin that is undeveloped. The magnesian limestone, from its deposition at the north-eastern extremity, rests unconformably upon and across the trough of the basin to the south-west extremity of the coal measures, when it reposes in a similar manner upon the millstone grit; and, with the exception of a small portion above the centre of the trough of the basin, throughout the whole of that extent, the upper beds of the coal measures rise up into, and terminate underneath, the limestone.

Mr. PHILIP WILLIAMS—It is not twenty years since I was at Seaton, in the neighbourhood of Newcastle, when Mr. Buddle and other eminent engineers contended that there was no coal there; but now Mr. Carer is working mines there, and raising large quantities of coal at the very spot where it was so confidently asserted that none could be found.

Mr. HALL—The limestone on the south side of the boundary line extends very much from the sea coast, and is of great thickness, the consequence of which would be that the coal seams would be thrown downwards to a great depth on the south side, so that it would be almost impracticable to work them with any expectation of profit, particularly if the quality be as inferior as that of the coal already found in the neighbourhood. I should think there would be something like eighty extra fathoms of limestone to cut through before you could reach the seam of coal; perhaps more, if the angle continued (as there is good reason to suppose) to dip towards the sea.

Mr. HANDELL COSSHAM—Mr. Hall, I suppose, is speaking of the magnesian, and not the mountain limestone?

The PRESIDENT—Yes, the magnesian limestone, which, it is stated, reposes on the coal measures.

Mr. HANDELL COSSHAM—There is no development of mountain limestone on the southern side?

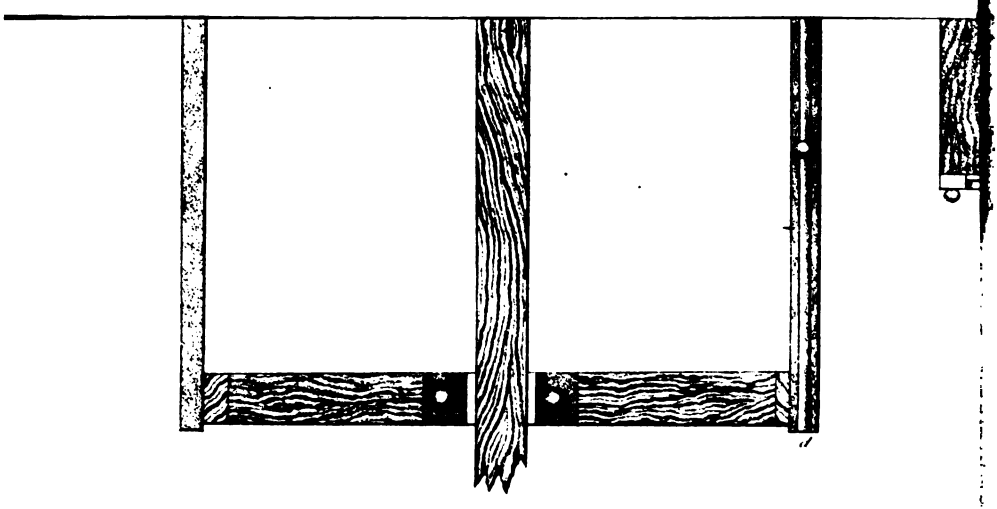
Mr. HALL—Yes, there is; but it is to the westward, and so faintly delineated on the plan as not to be clearly distinguishable from the place where we are standing. At Westerlee (twenty miles west from Castle Eden, where we find the magnesian limestone cropping out underneath

the new red sandstone), there is an outburst of mountain or carboniferous limestone. Westerlee, as I have already stated, is 1100 feet above the level of the sea. In Castle Eden Pit, the mountain limestone is 3000 feet below the magnesian; and on the Tees, at Yarm and at Croft, the new red sandstone and the magnesian limestone are covered by the lias formation. If, therefore, there really be coal in this district, it must lie at a very great depth indeed, and not likely to justify the expense of sinking after it for a long period to come.

The PRESIDENT—I do not know whether it is necessary to pursue this subject any farther at present. In a short time the extended mining operations of the district will, no doubt, be so far carried out that the subject will be more fully developed. At present, any speculations as to the extent of the coal-field under the superior formation are necessarily extremely uncertain. I will now, therefore, call upon Mr. Robert Aytoun, of Edinburgh, to read his paper on Safety Cages.

The thanks of the meeting were then unanimously accorded to Mr. Hall.

Mr AYTO



Side Elevation.

(Rope unbroken.)

mote getting into his eye, a momentary giddiness seizing him, his candle being blown out, being too late in getting hold of the lever—any of these occurrences may make him lose the proper moment for arresting the cage, when the fate of the occupants is inevitable, unless, indeed, the cage happens to be provided with safety apparatus and a disengaging catch. In the latter case, the rope is disengaged from the cage before it reaches the pulley, and the cage clings to the guide-rods high above the pit, with all its occupants safe and sound. It will not do, therefore, to say that these inventions may be rendered unnecessary by careful management, when it is notorious that the class of accidents to which they are best adapted, are exactly those which are most numerous in shafts, and of that character that careful management gives no impunity from.

Nor do I think there is much force in the objection, that the use of these contrivances would induce mine proprietors to run ropes, when no longer trustworthy. This might have been a good objection if their use had been made compulsory. But where the manager adopts them from motives of humanity alone, we have the best of guarantees against their abuse, and we may confidently reckon that untrustworthy ropes will never be allowed under his management.

But the chief objection which has been urged against the use of these inventions, is the small number of lives lost in shafts, compared with the large number of lives lost in the mine itself, by falls from the roof, explosions, &c. This is a very unfair objection, as it merely amounts to this, that there is no use in doing away with a certain number of deaths, because there is a much larger number of deaths which we cannot avert. But a reference to statistics will at once get rid of this objection, by showing the fearful risks which are run in going up and down shafts, and the comparative safety the miner enjoys during the hours he is actually at work below.

By the Inspector's Report just published, we find that the deaths occurring in shafts amounted to the number of 182 in the year 1860. A simple calculation in the rule of three tells us that if the miners ran the same risk, in equal spaces of time, during the twelve hours they are engaged in working the coal below, as they do during the two minutes employed in going down and up the shaft, the total number of deaths from all causes, instead of being 1109, as in the Report, would have amounted to the enormous sum of 65,220, a rate of mortality that would bring the present race of colliers to a close in a couple of years. This serves to show the fearfulness of the risk to which the collier is exposed in going

to and coming from his daily work, a risk which, I suppose, would scarcely be exceeded if he were exposed for the same space of time to the bullets in the planes of Solferino or Magenta.

Such being the case, it becomes the imperative duty of every one, according to his opportunities, to endeavour to put a stop to these fearful risks. The inventors, I must say, have done their parts. Following in the wake of Fourdrinier, who was not slow in taking advantage of the introduction of cages and guide-rods, they have now brought the safety apparatus to such a state of efficiency and simplicity, that it is worthy of being tried and tested in every colliery in the kingdom. If this were done, and the skill and tact of the colliery mechanics over the whole kingdom were brought to bear upon them, we should soon see them assume such a shape as would leave nothing to be desired. This would lead to other improvements in the shafts, such as fencing and walling, until at last the risk in the shaft would not be greater than in any other part of the mine. But whether or not we are to arrive at this happy consummation, depends entirely upon those who have the management of our collieries, and, I must say, upon the resolutions which such an Institute as this may, and ought to pass, upon this subject.

Having thus disposed of the various objections which are made to the safety cage, and which are neither better nor worse than the general run of conservative objections which have been brought against the use of almost every invention in turn, I beg leave to direct the attention of the Institute to the conditions which are necessary to insure the action of the safety cage. I do not here refer to the kind of grip or hold which the different safety cages take of the guide-rods; some of them may be better or worse than others, and members will have no difficulty in judging for themselves. But I allude to the conditions which must be observed for bringing the safety apparatus, whatever may be its nature, into play. In all safety cages which have been hitherto brought before the public, the safety apparatus is brought into play by the breaking of the rope in the following way:—The safety apparatus is provided with a spring, which tends to make it grasp the guide-rods. As long as the rope is entire, it compresses the spring and withdraws the apparatus from the guide-rods. But when the rope breaks, it is supposed to release its hold of the safety apparatus, and allow the spring to bring it into action by gripping the guide-rods. When the rope breaks near the cage, it invariably does so. But should the rope unfortunately break far from the cage, and perhaps on the other side of the pit-head pulley,

the drag of the long part of the rope which is still attached to the cage, called the tail-rope, may prove too strong for the spring, and so prevent the safety apparatus from coming into action. The obvious remedy is to increase the strength of the spring, so as to overhaul the tail-rope, whatever be the amount of the drag. But here we are met with the difficulty, that if we increase the strength of the spring beyond a certain point, the safety apparatus may chance to be brought into operation, although the rope does not break, by the irregular motion of the steam-engine, or its too great speed. This difficulty was suggested to me by Mr. Woodhouse, when I saw him in London two years ago. The best way of overcoming it appears to me to be to ascertain the amount of drag in each case, and to make the strength of the springs just sufficient to overcome it and no more. If this be done, we are sure of not bringing the clutches into action unnecessarily.

There are two cases. The simplest is where no part of the tail-rope acts by gravity against the falling cage. In this case the weight of the cage is expended partly in accelerating its own fall, and partly in accelerating that of the tail-rope which is attached to it, and the division of that weight is made exactly in proportion to the quantities of matter in the two bodies. Hence we have a ready way of estimating the drag of the tail-rope. Suppose it weighs one-third of the weight of the cage, then three-fourths of the weight of the cage are employed in accelerating its own fall, while the remaining one-fourth is employed in overcoming the drag of the tail-rope.

The other case is complicated, by part of the weight of the tail-rope acting by gravity against the falling cage. Here we get rid of the complication by setting aside an equal part of the weight of cage to neutralize the portion of the tail-rope which acts by gravity, and by dividing the remainder of the weight of the cage, or what I may call its free weight, among all the matter which is to be moved according to their quantities.

A simple formula, which I give below, will enable any one to calculate the amount of drag of the tail-rope in each case. The formula embraces both cases mentioned above.

Let t be the weight of tail-rope.

g that part of it which opposes, by gravity, the falling cage.

$$\text{Then the drag} = g + \frac{t \times \text{free weight of cage.}}{\text{total weight of cage and tail-rope.}}$$

Example.—Loaded cage, twenty cwt.; tail-rope, five cwt. on an inclination of one in ten from drum to pit-head pulley.

$$g = \tfrac{5}{10} = \tfrac{1}{2} \text{ cwt.}$$

$$\text{Drag} = g + \frac{t \times \text{free weight of cage.}}{\text{total weight of cage and tail-rope.}}$$

$$= \tfrac{1}{2} + \frac{5 \times 19\tfrac{1}{2}}{25} = 4\tfrac{4}{10} \text{ cwt.}$$

The strength of spring in this case should be five cwts.

DISCUSSION

ON

MR. AYTOUN'S PAPER ON SAFETY CAGES IN MINES.

The PRESIDENT, after the paper had been read, desired Mr. Aytoun to explain the two models on the table, it being the wish of the meeting that he should do so.

Mr. AYTOUN—The manner in which this individual cage [taking one of the models in his hand and exhibiting it to the meeting] acts is this. There is a clutch here in the nature somewhat of the key used by miners in boring deep borings. There are two jaws attached to a lever, which they put around the boring-rod and haul it up with. These two jaws lay hold of the guide-rods in a similar way, and prevent the cage falling, and these two clutches are brought into operation by springs below here. As long as the rope is entire, the springs are compressed by a clutch lever which presses upon them; but the moment the rope breaks, the springs come into play, knock down the end of the lever, and make the clutches seize hold of the guide-rod [holds the model up, releases the catch attached to the cage as if broken by an accident, and shows the operation of the clutches in seizing hold of the guide-rod]. Nothing you see can be simpler or more effective. There are a number of other contrivances and inventions made use of by others, which are exceedingly good, but I believe this is the only one which applies to wire-rope guide-rods, as well as to the ordinary wooden guide-rods. This [showing the other model] is an instance in which I applied it to iron guide-rods. Here is a hole made in a piece of iron, which serves for a slide along the guide-rod, but the mode in which it operates is this—the moment the rope breaks, it catches hold of the guide-rod, and then the same results follow as before [repeats the experiment with the second model, showing how the cage is held suspended in case of the fracture of the rope]. One advantage of the clutch which I have adopted is this, that it makes no impression whatever on the guide-rod. I have repeated this experiment

an innumerable number of times, and this [showing the surface of the guide-rod in the model] is all the injury that has been done to it. I now exhibit this disengaging catch [detaching it from the model and holding it up]. The rope is fastened to the shackle at the top, and the cage to the catch below. There is a ring of strong iron, suspended below the pit-head pulley and the rope works through it. Now, in the case of over-winding, that disengaging catch passes through the ring, and is compressed, the cage drops, and is arrested by the clutches before mentioned [holds up the ring, compresses the spring, and shows how the cage is disengaged and arrested].

The PRESIDENT—When the springs are compressed, they are of a less diameter than that of the ring?

Mr. AYTOUN—Quite so. When this goes through, it just shuts this part [releases the catch, and explains the operation]. One advantage in this, which I have not seen in other catches, is this. As long as the plates remain in this position [describing the position by exhibiting the model], there is no possibility whatever of the cage being disengaged. Holes are bored through all these plates, and a strong bolt is put in and rivetted, to prevent the possibility of the cage disengaging itself; but when it goes through the ring, the bolt is cut just as cleverly as it would be cut by a pair of shears.

The PRESIDENT—I presume the best course to adopt will be to have these models exhibited in the model-room, so that any gentleman interested (and I suppose most of us are) in the subject can examine them in detail. At the same time, I am quite sure that Mr. Aytoun will be happy to answer any questions which may be put to him on the subject.

Mr. HANDEL COSSHAM—I quite appreciate the object of the paper which has just been read to the meeting, but I must confess that I cannot but think there is always great danger in carrying these matters, which have reference to arrangements for securing safety in the working of the mine, too far, and I am afraid that very often their effect is, that by taking the responsibility off the shoulders of the enginemen to a certain extent, you are apt rather to increase the very danger which you are anxious to prevent, rather than to lessen it. I remember seeing a contrivance of this kind adopted in the Forest of Dean, and when the rope was run up, it caught the cage, and fully answered the purpose. Subsequently the cage was accidentally drawn up, and thus the whole concern failed. I do not mean to say that the invention at present under

discussion is not a good one, and one that is calculated to lessen danger, in the case of a rope breaking or of overwinding, but I think that the result of adopting inventions of this character must naturally be, that the enginemen will feel themselves released from a portion of their responsibility, and may become proportionably careless, the result of which may be accidents of other descriptions. It strikes me also that several things must necessarily be assumed in reference to this invention. We must, for instance, assume that if the cage drops, the guides will be sufficiently strong, because I presume that if the guides broke, the cage would go to the bottom.

Mr. AYTOUN—Certainly, and so it would in ordinary cases if the rope only were to break. You now assume that something additional, namely, the guide-rod breaks.

Mr. HANDEL COSSHAM—It also appears to me that a spring like that described would be very liable indeed to derangement. All things in connection with springs, we know, are peculiarly liable to derangement, from the number of causes natural and otherwise, which at different times affect the elasticity, and consequently the grip of the spring. This invention assumes that the springs are all right, the guides are all right, and the cage is properly fixed. I hardly know what opinion to give with respect to an invention based on so many assumptions.

Mr. WOODHOUSE—Without entering upon any inquiry as to what will probably be the result of the invention described in the interesting paper which has been read to us, I think Mr. Cossham will agree with me that it is hardly fair to draw a conclusion prejudicial to the utility of an invention, by assuming that its several component parts may not be in working order, or may be imperfectly formed. On the contrary, Mr. Aytoun, in my opinion, has a perfect right to assume that the springs will be strong enough, and the guide-rods of such a description as to resist the pressure of the springs without breaking; he is also entitled to assume that the slides will be strong enough, and that the whole of the machinery is in good working condition. Certainly no one could advocate the adoption of an invention of that kind, if it could be shown that it was liable to get out of order every minute. Probably we shall have some further opportunity of testing the merits of the invention.

Mr. HANDEL COSSHAM—I may mention that, among others, I have seen a very good arrangement in the safety break of Hogden, by which the engine is pulled up before the cage gets to the top; and if the engineman forgets his duty, there is a finger which catches the cage, and puts

on the brake. I have seen several cases in which the cage has been pulled up within a yard, even when the engine has been running full speed.

Mr. Fereday Smith—I think one cause of accidents in coal pits, allied to the class which is now under discussion, arises from forgetting that the greatest strain on the rope is at the first starting of the engine. As an illustration, suppose a heavy waggon, on an ordinary road, with horses attached to it; the greatest strain is on the first moving of the waggon; once in motion, the strain is less. It is clear, also, that the strain is greatest in starting the load from the bottom of the shaft; I have tried the effect of a spring immediately over the cage, and not only is it a saving of the strain on the rope, but I believe it is a great security for the life of the men; and that a mine is much safer where this principle is adopted than where it is not adopted. I am particularly grateful to the gentleman who has read this paper, for drawing attention to the counteracting influence of the tail-rope in the case of a fracture a long way above the cage. I believe the reason of the accident to which Mr. Cossham has alluded, being so disastrous, was, that they were not able to counteract the action of the spring, when the rope broke many yards above the cage. I think that this invention, if it is properly worked out, and its details attended to, will prevent the occurrence of many fatal accidents.

The President—I believe the spring to which you allude is very extensively used in the North of England, but I am afraid that practically they lose their elasticity by continual action, especially where the action loaded is upwards of 1000 times a day, and with the empty tubs as many times. This has always been felt as one of the difficulties which is experienced in the use of the spring, and probably if the attention of the gentlemen who are present were directed to this defect, a remedy might be discovered. It is certainly very important to prevent the shock and strain upon the rope on the lift of the cage from the bottom of the pit, and also any irregularity of strain whilst drawing the tubs to bank, and I think we are much indebted to Mr. Aytoun for bringing the subject before us. It is very important, inasmuch as we have occasionally accidents arising from the machinery getting out of order, and it is very necessary that we should not cease in our endeavours to make those improvements which may tend to the safety of the men. I think the present invention is well worthy the attention of the trade; it seems a simple one, and well adapted to accomplish the object, and it is, therefore, well worthy of consideration if it can be effectually carried out, and brought into general operation.

Mr. Fereday Smith—I observed, Mr. Aytoun, that you stated, while quoting the report on accidents in coal mines, that the total number of accidents in shafts for the year 1860, of a fatal character, was 182. I wish to know whether these accidents were all caused from the breakage of the ropes, or were they accidents in shafts from various causes?

Mr. Aytoun—Accidents in shafts from all causes.

Mr. Berkley—I think it will be found, on examination, that by far the greatest proportion of the per centage of deaths in shafts is owing to other causes than the want of safety in cages, and that the improvement in cages will not materially decrease that per centage, even supposing that they are made perfectly safe. Many accidents occur by falling out of cages, by stones falling, by men falling when in the shafts, and through other causes not remediable by this invention, and which have nothing whatever to do with the safety of the cage.

Mr. Aytoun—I quite admit that, but I think that if you were to make the cage perfectly safe, you would soon turn your attention to making the walls of the shaft safe, and every part of the transit from top to bottom perfectly secure.

Mr. Daglish—There seems to be another objection to the use of this safety cage in very deep shafts. Supposing the breakage of the rope to occur near the lift, the question is, can the guide-rods be made sufficiently strong to bear the weight of the rope falling down the pit, some of these ropes weighing something like five tons each. I am aware that various arrangements have from time to time been used for securing the safety of the cages in the North of England, but I believe they have all been abandoned, from their liability to become deranged, and I very much fear that the guides could not be made sufficiently strong to resist the momentum of the falling rope.

Mr. Aytoun—I should suppose that there could be scarcely any danger of that, because the guide-rods could be made of any strength you please. There is not the slightest danger of the guide-rods not being sufficiently strong. The five tons of rope would, of course, come down gradually, and their accumulated weight would only make the hold the more secure. The principle of this invention is, the greater the weight the stronger the bite. There is absolutely no possibility of releasing it.

Mr. Daglish—Precisely so, supposing that the material will resist the weight.

Mr. Aytoun—We will take the best and the strongest material.

Mr. Daglish—I merely raise this objection to the general principle,

for the consideration of the meeting, and not in its application to this special invention.

Mr. GREENWELL—Have these springs been in use in any colliery long enough to show to what extent they deteriorate, or whether they are open to the objections which have been urged against them by Mr. Cossham?

Mr. LANDALE—I have had Mr. Aytoun's cages constantly in use at one of our pits for upwards of two years, and I can give my testimony in favour of them. They answer very well, and the expense of keeping them in order is very trifling. The cages are regularly examined to see that they are in working order. The springs have occasionally been tempered afresh, and after being in use for two years the whole apparatus is as good as ever. As to the strength of the guide-rods, I may say that they are four inches square, and there are four guide-rods to each cage. They have been repeatedly tested with a weight of two tons on the cage, and the indentation it makes is very trifling indeed. There is also another point of advantage, the catch itself, when disengaged, does not seem to drop in any degree: it catches immediately, so that the moment the cage drops, the catch operates within two or three inches. Of course it catches before any momentum is gained, and there is no kind of jerk brought on the rod. The simplicity of the whole thing is its great recommendation, and another advantage is, its being so easy to keep in order. Mr. Aytoun has suggested an improvement, whereby the springs do not require to move nor the joints of the lever, which, I think, may be an improvement, but not having tried it, I cannot speak with any degree of accuracy respecting it.

The PRESIDENT—Do you find the tendency of the spring is to become weak and inelastic by continuous use? Have you made any experiments in order to ascertain the effect of continual use upon the elasticity of the springs?

Mr. LANDALE—Yes; most of the gentlemen here will have experienced this in various ways. All springs, particularly those that are exposed to heat in steam engines, very soon lose their elasticity. I have, therefore, looked carefully at that point.

Mr. BERKLEY—About what quantity of coal is drawn per annum in the colliery in which this safety cage is in operation?

Mr. LANDALE—The colliery is not in full operation yet. It draws probably about from 60 to 100 tons a day.

Mr. DICKINSON—I think it would be a very unfortunate thing indeed if the merits of this invention should be talked down by some of the

mining engineers who have had no practical experience of its working. We are too far off the model here to see what is the nature of its construction, but in Lancashire and Cheshire, where there are a large number of safety cages working, their introduction has been attended with the greatest possible success. They do not always catch the cage, it is true, but I should say that in twice out of thrice they do so most successfully. We have at least 100 of them, and seventy per cent. of them have proved a great success. I do not mean to say that the cages are everything which they might be, even now. No doubt they are susceptible of improvement, and perhaps if this one were narrowly examined, some further improvements might be pointed out.

Mr. Hood—On the simple question of the springs, I may be allowed to state that many of these safety cages are used in our pits in the neighbourhood of Glasgow, and we find the springs last three or four months, but at the end of that time they get weak. We have had several accidents from overwinding, and I am happy to say that in every case the safety apparatus has operated successfully. In one case the cage went up past the head of the winding machinery, and through the operation of the safety apparatus, it was firmly fixed, notwithstanding it had more than a ton weight on it. I have had frequent occasion to see the arrest of the cage through the working of this invention, and can bear testimony to its great utility.

Mr. Frederick Smith—After what has been said about springs, I cannot allow this opportunity to pass without testifying to the great advantage of springs, especially when used under certain circumstances, such as the raising of water barrels. When these springs are used on the compression principle, and not on the expanding principle, they are certainly found, as far as my experience enables me to judge, most effectual, and to ensure the greatest amount of safety to the miner. The result of the use of such springs is, that the rope will endure a much longer period of time than it would if they were not used, and indeed in some cases the presence of such springs will ensure the rope or chain lasting twice as long.

Mr. Daglish—In reply to Mr. Dickinson's observation, I am sure there is not the slightest wish in the world to talk down this invention, and, indeed, the very fact of the discussion having been so prolonged, shows that there exists only one desire on the part of those present at this meeting, and that is, to elucidate the truth. Safety cages in various forms have been tried at several large collieries, and have been found not

to answer, and therefore it was quite necessary that gentlemen present who have tried them, should give the result of their experience. Whenever any invention of this kind is brought forward, it is necessary that it should be well ventilated before it can be expected to be brought into general operation, however valuable it may apparently be.

Mr. MATTHEWS—I may state this in favour of springs, namely, that some time ago we used a biting apparatus at the end of the rope, but it did not answer. We have taken that off, and have now adopted springs on the portion of the drum where she takes the lift. So far as we have tried them we have found them answer much better. They are placed round about one-fourth of the drum.

The PRESIDENT—Instead of the springs being at the end of the rope?

Mr. MATTHEWS—Yes; we added them to the drum where she takes the lift.

Mr. WOODHOUSE—There was one observation which was made by Mr. F. Smith—I think he mentioned the drawing of water barrels—will he allow me to ask whether the rounding-off of the barrels had not something to do with lessening the resistance?

Mr. FREDERICK SMITH—There is a valve, and that is to be considered in the rounding-off process.

The PRESIDENT—Still I am afraid the rounding-off would not overcome the *vis inertiæ?*

Mr. FREDERICK SMITH—No; but it would lessen it.

The PRESIDENT—Have you examined the cage now, Mr. Dickinson?

Mr. DICKINSON—Yes, I have; and it seems to me to have some very good points about it. The only thing which I do not like is the twisting. There is no such objection with respect to Owen's apparatus which we use in Lancashire and Cheshire. The practical difficulties of cutting where it does not act are entirely got rid of, and it is a great success in seventy cases out of one hundred.

The PRESIDENT—Gentlemen, I beg to move that the thanks of the meeting be given to Mr. Aytoun, for bringing the matter forward, and for the able paper which he has read.

The motion having been seconded, was carried by acclamation.

THE NEW YORK
PUBLIC LIBRARY
ASTOR, LENOX AND
TILDEN FOUNDATIONS

ON THE

NORTHERN END OF THE BRISTOL COAL-FIELD.

By HANDEL COSSHAM, Bristol.

I am a little fearful, that in undertaking the responsibility of attempting to give you information relative to the subject of this paper, I am almost laying myself open to the charge of presumption, for I am quite aware that there are many members of the Institute far more capable of writing a paper on this subject than I am.

I felt, however, that I should not be justified in withholding any information I could afford, however slight, on a subject which I have had many opportunities of investigating during the last fifteen years, and as far as I am aware no paper has yet been laid before this Institute directly bearing upon the subject I have engaged to treat.

Mr. Greenwell has, I know, written, and written well, on the southern end of the Bristol coal-district, and it is my intention, therefore, specially to confine my remarks to the northern end of this small, but interesting coal-field.

And, first, let me call your attention to the boundaries and area of the district on which this paper is intended to treat. It is pretty accurately defined by the geological survey maps, and also by the large map, which I have had specially prepared for the purpose of illustrating this paper. (See map 1.) A glance at this will show you that the northern end is clearly shown by a well-defined ridge of mountain limestone, which rests upon a base of old red sandstone, which can be seen backing the limestone round most of the northern end of the coal-field, and is well developed at the north-east end of Wickwar tunnel.

The mountain limestone at most of the points where it can be seen round this part of the basin, dips into the field at angles varying from

30° to 60°, and abounding in the principal fossils of this period, inclu[redacted] those members of the *brachiopoda class*, consisting of *productus*, *spir*[redacted] *rhynconella*, *orthis*, *terebratulæ*, and various remarkable corals.

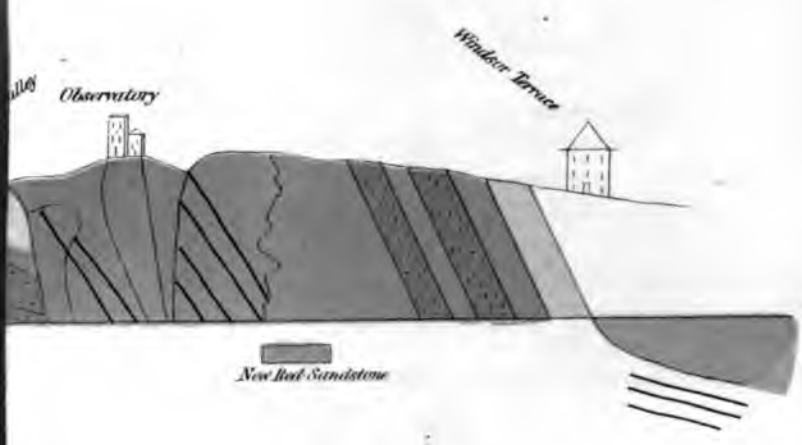
The mountain limestone in this district is from 600 to 1000 yard[redacted] thickness, taken at right angles with the dip, and is also distingui[redacted] by having a thin bed of coal about six inches thick some 200 yards b[redacted] its upper surface, and which can be seen in that magnificent section ([redacted] haps the finest in the world) at the side of the Avon at Bristol. [redacted] section No. 2.) It may not be altogether out of place for me to rem[redacted] here, that this gorge of the Avon developes one of the most remarka[redacted] and beautiful "faults" that is to be seen in any part of the count[redacted] the result of which has been to throw the millstone grit over, and [redacted] it into the crevice formed by the rupture, and which now forms t[redacted] beautiful nightingale valley so interesting to lovers of fine scenery, well as to lovers of a more interesting kind.

One peculiarity of this fault is, that the grit continues to sink here [redacted] the extent of several inches every year, and is also bent and contorted [redacted] the most striking and interesting way. Before quitting the mounta[redacted] limestone series, I may remark that perhaps in no part of the world c[redacted] this rock be better studied than in the neighbourhood of Bristol.

Immediately upon the mountain limestone we have well developed th[redacted] millstone grit, which, as usual, is thickest at the northern end, developing at Cromhall and Yate to the extent of 400 or 500 yards in thickness. I[redacted] is, as far as I know, barren of coal seams, but round some parts of th[redacted] district is so fine grained and silicious that it is well adapted for grinding up to make fire bricks, and when mixed with a portion of a suitable fire clay, will make a very useful and valuable fire brick. I have lately used considerable quantities for this purpose, in the proportion of about three-fourths of ground grit rock with one-fourth of the fine china clay from Cornwall, which, as you are no doubt aware, is composed of the disintegrated felspar, washed down from the granite hills of that interesting district.

Having spoken of the rocks that form the base of our coal-field, let me now give you, as accurately as possible, its area.

Taken from the north end at Cromhall to the apex of the anticlinal that crosses the field from east to west at Kingswood, its length is ten miles; its widest part is in a line with the said anticlinal, and is seven miles; its average width, however, cannot be taken at more than five miles, and the area is therefore about fifty square miles. The portion of



MECHANICS INSTITUTE

10,000,000 tons of which I estimate is already worked, leaving 30,000,000 tons more to be wrought by the energy, capital, and skill of the future.

The present output of this series I estimate at about 250,000 tons a year, and at the present rate of production, therefore, this part of the basin will be exhausted in 120 years. The coal in this series is highly bituminous and free-burning, and is chiefly adapted for household and gas purposes. A great north and south fault passes through the series, and completely divides the Coal Pit Heath Collieries, on the western side, from the Park Field, Brandybottom, Dudley Pit, and Shortwood Collieries on the eastern side. It is a fault that raises the strata on the western side from 200 to 300 yards, and I believe was caused at the time when the silurian rocks of Mayhill, near Gloucester, were upheaved, as

17322

the fault can be distinctly traced from that point through the centr the coal-field, and for many miles south of Bristol.

In the Pennant series, which immediately underlies the above, . seams have been noted, but I only know of three that are workal They are respectively called

	Ft.	In.
The Cock - - - - - - -	2	2
The Hen - - - - - - - -	1	10
The Chick - - - - - - -	1	0
Total - - -	5	0

The total area of this series is about eight square miles, or 5120 acres; and taking our former estimate of 1250 tons to the acre per foot thick, that will give 6250 tons to the acre in the three seams named, and a total quantity in the series of 31,500,000 tons. Very little of this coal has been worked; but as the sinking is excessively hard and very heavily watered, and as the roof over the coal is in most cases rock, and yields a large amount of water, and, further, as over three-fifths of the entire area the depth would be very considerable, I think that we ought not to take the coal that can be worked at a profit from this series at more than 10,000,000 tons. This coal is chiefly adapted for smiths' purposes, and is very friable and soft in its nature, yielding a large proportion of small.

The Pennant rock is a silicious grit rock, interstratified with thin beds of ironstone and bands of coal, and in some parts with coal shales, and forms a very distinguishing feature of all the coal-fields in the south-western district of England and Wales. It derives its name from a place called Pennant, where it developes very finely, in South Wales. (See section 4.)

I now come to the largest and most important division of seams in the Bristol Coal-field, namely, that series immediately below the Pennant, and which I estimate at 900 yards thick. I take the total area of this series to be forty square miles, and supposing we deduct the eight square miles covered by the last series (the Pennant) as being too deep to work, and suppose we also deduct seven square miles more for the coal already worked, wasted, and faulty, we then have twenty-five square miles left to work, and I think we may fairly calculate upon having that quantity, and in this series I estimate there are fifteen veins of workable coal (excluding all under fifteen inches thick), of an aggregate thickness of three feet, and taking our former estimate as the basis of our present

LIBRARY

THE NEW YORK
PUBLIC LIBRARY
ASTOR, LENOX AND
TILDEN FOUNDATIONS

calculation, we arrive at the conclusion that there are 37,500 tons to the acre in this series, or 24,000,000 tons to the mile, and 600,000,000 tons yet to work.

This coal varies a good deal in character, but it may chiefly be regarded as a half-bituminous and half-steam coal. The dip is also various, but may be taken as varying from 15° to 45° in the collieries now worked.

It is in this series that the celebrated Kingswood Collieries have been worked for the last 150 or 200 years; and we have now pits working in the veins in this series to a depth of from 400 to 500 yards. A railway is now being constructed across the western side of our coal-field, to connect Bristol with the South Wales line; and I have no doubt that this will open up the veins in this series very extensively by and by. It may also be taken as a rule, that the veins below the Pennant are not so heavily watered as those in and above that rock. (See section 5.)

I now come to a very difficult question, viz., the identity or otherwise of the Bedminster veins with the Kingswood and Easton, and I have been led to alter the views I once held on this point, and to come to the conclusion that the Bedminster viens are below the last-named series; for I find it impossible to identify the sinking in the two collieries. There is a much greater proportion of stone in the sinking at Bedminster than at Kingswood, and the veins are much more sparingly deposited. Only four veins are found in the Bedminster series, and of these only two are workable, and these are called

	Ft.	In.
The Top Vein - - - - - - -	3	6
The Great Vein - - - - - - -	3	6
Total - -	7	0

If I am correct in this opinion, it follows that these viens would be found *under* the Kingswood veins; and at Soundwell, I am informed, the strata below the Great Vein at Kingswood was proved for ninety fathoms, without cutting the Bedminster veins, and it follows, therefore, that if there, they must exist below that depth; and I think the probability is they are some 150 fathoms below.

It is, of course, difficult to calculate the workable area on these veins with accuracy. The probable extent they cover is about forty-five square miles, but I think, at any rate, we must deduct twenty-five square miles from this for coal worked and out of reach. That would leave twenty square miles yet to work, which, at seven feet thick, would give an aggregate quantity of 112,000,000 tons, being 8750 tons to the acre, and 5,600,000 tons to the mile. (See section 6.)

The ground below this has been proved to the *Ashton* or lowest series, and they are about 200 yards below the last, or Bedminster series; and here there are three principal seams, namely:—

	Ft.	In.
The Top Vein - - - - - - -	3	6
The Great Vein - - - - - - -	4	0
The Little Vein - - - - - -	2	4
Total - -	9	10

These veins are somewhat irregular, and it would not be safe to calculate them at more than nine feet thick. They are, no doubt, analogous to the Vobster seams at the south end of our coal-field, near the Mendip Hills.

The coal is exceedingly friable and non-sulphurous, and well adapted for the manufacture of iron—showing the wisdom and benevolence of Him by whose power and skill our globe was arranged in its present state, and made fit to be the abode of man, in thus placing this coal nearest to the most extensive beds of ironstone in the district; for we find several important and useful bands of ironstone in this series, and which have lately been brought into use through the enterprise of Messrs. Knight and Co.

The quantity of coal that can be worked from these veins is an interesting question. I estimate the entire area of the series at fifty square miles, and at nine feet thick would give 11,250 tons to the acre, and 7,240,000 tons to the mile. I think, however, we must deduct thirty-five square miles for coals worked in these veins and out of reach, and that would leave 108,600,000 tons as the total quantity to be expected from this series.

Let me now summarize the results at which we arrive. They are as follow:—

					Tons to Work.
Above the Pennant	4 seams—	area, 5 sq. miles—	thickness, 10 feet		30,000,000
In the Pennant.....	3 „	„ 8 „	„ 5 „		10,000,000
Kingswood series 15	„	„ 25 „	„ 30 „		600,000,000
Bedminster veins.....	2 „	„ 20 „	„ 7 „		112,000,000
Ashton series	3 „	„ 15 „	„ 9 „		108,600,000
	27 workable veins.		Total thickness, 61 ft.		860,600,000

This gives twenty-seven workable seams, of an aggregate thickness of sixty-one feet, and a total quantity of 860,600,000 tons to work, and I think it not improbable that 1000 millions of tons may yet be worked from the northern end of this coal-field.

There are one or two other points of interest which, with your permission, I will refer to.

1st. That with very slight exception the whole of this field is free from carburetted hydrogen gas, and it would no doubt be a most interesting enquiry as to why that is the case.

2nd. With one or two exceptions this field gives the greatest aggregate thickness of coal of any field in this country.

3rd. The dislocated and contorted character of our basin makes it exceedingly difficult to work out, and obliges me to speak with more caution and care than would otherwise be quite justifiable, and somewhat confirms the statement once made by, I believe, that eminent geologist, Sir Henry de la Beche, that any man who could work out the geology of twenty-five miles round Bristol, was fit for investigating the geology of any part of the world.

4th. The overlie over the Bristol coal-field is remarkable and interesting, consisting of the new red marls, the lias, and sometimes the oolitic, and no doubt, but for this covering, the Bristol coal-field would have been much more exhausted than it is.

5th. I believe a good deal of hematite iron ore might be obtained (though chiefly lying in pockets) in the mountain limestone and pennant rock, and that bands of carboniferous ore could also be worked in the Kingswood and Bedminster, and more extensively in the Ashton series.

6th. I have not said much about the Yate seams, which develope at the northern end of our coal-field, and it is extremely difficult to identify these with any of the others to which I have referred. The character of the coal is adapted for locomotive purposes, but is very inferior as a house coal. The Pennant and millstone grit are here brought within 100 yards of each other, and it is evident that a large proportion of the seams below the Pennant have been denuded, and the others are pinched up and lifted to an angle of some 45° and above.

7th. There is another point I think it right just to notice, namely, the nature of the rock forming the anticlinal axis at Kingswood, which is shown on the Government survey maps as "grit;" but I am quite satisfied, after a careful examination, that it cannot be the real millstone grit, as the coal is found below it in regular order. I believe it to be one of the sandstone beds of the coal measures brought to the surface, and which has somewhat deceived our geological survey friends. At the same time I may remark that I believe the same upheaval that lifted this anticlinal axis also split the mountain limestone at Clifton, causing that deep

gorge to which I have previously referred, and also that very remarkable dislocation at Wick, on the eastern side of our coal-field.

I hope I shall be excused for having detained you at such length on this subject. It is one that is interesting to me both geologically and commercially, and I think the best way to increase the valuable fund of information already collected and published by this Association, is for every member to contribute his quota in the district with which he may be more especially connected; and hoping you will excuse the imperfections in this paper, which has been very hastily put together, I now beg to place it in your hands.

ON THE SOMERSETSHIRE SECTION

OF

THE BRISTOL COAL-FIELD.

By G. C. GREENWELL, Bristol.

Taking the river Avon as the northern boundary of this section, the remainder of the boundary of it may be taken approximately to pursue the following line.

Commencing at Ashton, it takes a southerly direction to Winford and West Harptree: thence it passes south-east to Chewton Mendip, and Ashwick: thence east to Coleford and Mells. From this latter point, northward, we have no means of knowing what the fact may be, owing to the cover of the older strata by the lias and oolite; but if we take the position of the mountain limestone into consideration, as developed at Frome, Wick, and Chipping Sodbury, we may be justified in assuming that the east boundary of this division of the Bristol Coal-field will be from Mells to Frome, and thence by Norton St. Philip to Bath.

This boundary incloses an area of about 150 square miles. The greater part of it is covered by the overlying formations, and where the surface of the country is most elevated we find the greatest number of them. Thus, while in the valleys of Radstock and Radford, the coal measures are only covered by the magnesian conglomerate and new red sandstone, on the more elevated positions of Norton Hill and Timsbury, they are covered by the lias; and still higher, as at Braysdown (about six miles south-west of Bath), the coal shaft commencing in the inferior oolite, passes through, in succession, the lias, new red sandstone, and magnesian conglomerate, before penetrating the coal measures.

From the circumstance that these upper formations are unaffected by many of the great faults which intersect the coal measures, and from

their horizontal character, when uninfluenced by those dislocations which have occurred since their deposition, it may fairly be inferred that at one period the whole of this district was overlaid by them, and that excepting so far as depressions have been occasioned by the more recent convulsions of nature, the present condition of the country, as to their presence or absence, is the effect of denudation entirely.

The coal measures of this district seem to form themselves vertically into two great divisions, the upper division resting on the Pennant rock, and the lower lying between the Pennant rock and the millstone grit, which occupies here the same relative position as in the other great coal-fields of this country.

I propose to describe these divisions separately.

1*st*. *The Upper Division.*—The upper division, the probable thickness of which is not less than 2500 feet of shales and grits, with coal interspersed, subdivides itself naturally into two series of coal-bearing strata, separated from each other by from 500 to 600 feet of strata barren of coal: a prominent member of which is a stratum of red and green shale of 150 feet in thickness. The upper or first of these is sometimes called the first, and sometimes the Radstock series, and where this series is found at its greatest depth from the surface, the coal measures of Somersetshire present their deepest section, their entire thickness probably not being far short of 9000 feet.

The extent of the first series proved is limited; it does not in all probability extend beyond a line drawn from Farmborough by Dunkerton, Foxcote, from this to a mile south of Radstock, and thence by Midsomer Norton to Paulton. Between Paulton and Farmborough the limit is not known with exactness, and it may extend considerably north-west of a line between these two points.

The area comprised within these limits is about sixteen square miles, and the thickness of workable coal contained in it (although the aggregate thickness of the first series is not unfrequently eleven or twelve feet) cannot, I think, be taken as an average at more than eight feet, as generally, either in one place or another, one or two out of its six seams of coal is found in an unworkable state.

The seams of coal contained in the first series lie in about 360 feet of stratification, and the depth of the lowest, at the bottom of the basin, is not more than 1200 feet. The quality of the coal of this series is good, and adapted to household purposes, being very durable, and producing a

clear, hot fire. It is a coking coal, but the coke produced from it is sulphury and of an inferior character.

It is not my intention, in this paper, to give the details or sections of the various coal strata and seams of coal, as I have already, so far as would have been admissable into a paper of this character, done so in a paper read at Newcastle in 1854, and in another read at Cardiff in 1858, and more particularly as I hope shortly to present a paper to this Institute, containing these details in full.

I may mention that the coal of this series is absolutely free from fire-damp. The roofs are usually blue shale, and the thills a coarse fire clay.

The Second or Farrington Series.—From the top of the strata containing this series (immediately underneath the red and green shale before alluded to) to the top of the Pennant rock may probably be from 1000 to 1200 feet.

According to Messrs. Buckland and Conybeare ("Transactions of the Geological Society," 1824), the western border of the second series "follows an indented line from Brislington to Burnett, Pensford, Stanton Drew, Bishops Sutton, Chilton, Farrington Gurney, and Midsomer Norton." As, however, it is known that the Radstock series crops out close to this latter place, the boundary of the Farrington series must be placed somewhat further south, say as far as Chilcompton, and as the strata rise rapidly along the southern outcrop, being in some places perpendicular, there is probably not much area of the Farrington series belting the Radstock series on the south and south-east, but excepting that the coal proved at Twerton belongs to the lower division, there is nothing by which the exact boundary of this series may be determined. It may be assumed to pass by Kilmersdon, Wellow, and Corston, to the Avon.

These limits inclose an area of eighty square miles of Farrington seams, of the united thickness of ten feet of workable coal, after allowing for the occasional absence of one or two of the seams. The Farrington seams are worked at Timsbury by a pit which passes first through the Radstock series, and it is only in the very bottom of the basin where the depth to the bottom of the Farrington series would render the cost of winning them too great. Deducting, however, ten square miles from eighty, leaves seventy square miles of the Farrington series within easy access. The quality of some of this coal is good and adapted to household use;

its general character, however, is less bituminous than that of the first series. It contains less sulphur, and is a fair steam coal.

The coal of the Farrington series is not entirely free from fire-damp, as a little has been seen in working it at the Grove Pit at Timsbury: it is not, however, of any consequence.

Before proceeding to the second division, a few words about the Pennant may not be out of place.

This great mass of rock is probably 600 feet in thickness; in appearance it varies much, being in some places compact and close grained, with a bluish colour. When in this form it works well, and produces substantial masonry of a very beautiful appearance. In other places it splits well into flags, for which purpose it is much used. It presents these characters at Temple Cloud and between Keynsham and Bristol, at both of which places it is quarried to a considerable extent. It is exceedingly hard to sink through, and excepting towards its crop would, in all probability, form a considerable, though not an insuperable obstacle to the sinking of pits to the seams of coal contained in the lower division of the coal-field.

This rock is also seen in the cutting of the turnpike road half a mile south of Pensford. It is here of a dark reddish brown colour, with rolled nodules of stone and coal contained in it, and bears a strong resemblance to a bed of grit lying above the middle vein of coal of the Radstock series.

It is not entirely barren of coal, and a thin seam was worked in it by a pit about a mile north-east from Temple Cloud. It is also seen near Holcombe, in a quarry north of the brewery, where it is dipping north at a considerable angle; it is here flaggy. At Newbury, about two miles further east, it is of a rather softer nature, still flaggy, but dips south, and this circumstance will be referred to further on.

From this point along the eastern portion of the coal-field, the Pennant is covered by the overlying formations.

2*nd. The Lower Division.*—The boundary of the coal measures of the Somersetshire section of the Bristol Coal-field has been already described; but the area of millstone grit and coal shales beyond the outcrop of the lowest coal seam must be deducted from the entire area (150 square miles), in order to arrive at an estimate of the extent of district containing the coals of the lower division. I assume this allowance at half a mile in breadth along the whole boundary, thirty-six miles in length,

and this reduces the area of available coal-field to 132 square miles. From this area, I think, should be deducted the whole area of the upper division, viz., eighty square miles, under which the great depth, in conjunction with the Pennant rock, would, in all probability, preserve the coal of the lower division for a period useless for us to estimate. This would leave fifty-two square miles as the available area of accessible coal in the lower division of the district in question. There is a large quantity of coal in this division, probably in the aggregate not less than from fifty to sixty feet in thickness. If we take the thickness of the upper division with that of the millstone grit, say together 3000 feet from the total thickness of the coal measures, we have the great thickness of 6000 feet, or say 1000 fathoms to the bottom of the coal measures at the crop of the upper division. At this point, therefore, we may calculate on working the coal contained in the upper 300 fathoms of the lower division, which, with the thickness of the Pennant, would require a pit 400 fathoms deep.

Of course, it must not from this be assumed that I am giving it as an opinion that 400 fathoms is to be the limit of coal working; but I think it deep enough to found calculations upon, so long as districts are to be found where the depth is more moderate. In this depth of 300 fathoms are nineteen feet of coal, and no less thickness than nineteen feet would be found in any pit sunk 400 fathoms, supposing the upper 100 fathoms to be Pennant rock. From this circle (the crop of the upper division) to the crop of the coals of the lower division, the pits would be shallower and the coal more abundant. I will, however, estimate that fifteen feet of coal are obtained by pits which may be sunk to work the lower division of the district. The quality of the coal of this division is very different from that of the upper division. The coal of the lower division almost universally burns to a white ash, and is not a good house coal; that of the upper to a red ash, and is suitable for house use.

The coals of the lower division are frequently three, four, five, or even six feet in thickness; those of the upper rarely exceed two feet. The coals of the lower division in some localities evolve fire-damp; those of the upper do not. The coals of the lower division are free from sulphur, make good coke, and are excellent smith coal; those of the upper are sulphury, and will not do for either coking or smith's purposes.

The strata of the lower division contain clay iron ore in considerable quantity, and the blast furnace recently erected at Ashton, near Bristol,

is almost entirely supplied by that produced from the adjoining colliery of Ashton Vale. The furnace and colliery are contiguous to each other, the latter producing the ore and fuel.

The fire clays under the seams of coal of this series generally are of great purity, and the fire bricks made from them are of excellent quality.

The following is an estimate of the quantity of coal which remains in this section, allowing for loss underground:—

1. *Upper Division*—16 square miles × 8 feet thick =		98,304,000
70 square miles × 10 feet thick =		537,600,000
2. *Lower Division*—52 square miles × 15 feet thick =		599,040,000
		1,234,944,000
Deduct already worked—		
300,000 tons per annum for 100 years		30,000,000
		1,204,944,000

The great bulk of this coal-field is dormant, although within an average distance of the great market of Bristol, possessing a river navigable by ships of 2000 tons burthen, from the want of railway accommodation.

In a former part of this paper, reference was made to the southern dip of strata at Newbury. It is not believed that this change in the dip is the result of an anticlinal, but that here the strata are thrown back over. If so, this occurred at the period of the upheaval of the Mendip range of hills. At Chilcompton the dip of the coal measures is to the north, at an angle of about 18°; at the Old Rock Colliery it becomes steeper; at the Sweet Lees Pit, about two miles south of Chilcompton, it is 37°; about half a mile east of this, the strata are vertical; further east, the dip is to the south at a great angle; and still further east, at Newbury, the dip is south about 45°. The seams of coal here are all upside down, the hard shale roof (that should be) being at the bottom, and the soft thill at the top of the seams. And here occurs a most remarkable circumstance:—the same convulsion that threw over the coal measures threw masses of limestone along with them, and those marked on the geological map of the Ordnance survey are not, as there represented, the result of the faults ingeniously placed there, but masses detached from the Mendip range of limestone situated about a mile to the south. Men now living have worked in coal beneath

these masses of mountain limestone. It follows that a pit sunk to these coals where they dip south, would, if continued downwards, again pass through the same seams of coal.

In the neighbourhood here referred to, although the dip of the strata varies from 45° to vertical, and the seams of coal in some places are, with their bands, six or seven feet thick, a system of long work is practised, the goaf below being filled with rubbish and small coal, forming a floor for the workmen to stand on while bringing down the coal overhead.

In working with such inclination, ascensional ventilation seems essential.

DISCUSSION

ON

MR. HANDEL COSSHAM AND MR. G. C. GREENWELL'S PAPERS ON THE COAL-FIELDS OF SOMERSETSHIRE.

The PRESIDENT having announced that the meeting would now proceed with the discussion of the papers read by Mr. Handel Cossham and Mr. Greenwell on this subject,

Mr. HANDEL COSSHAM said—Before the discussion proceeds, allow me to repair an omission. I forgot to give an estimate yesterday of the quantity of coal which is raised annually in the Bristol coal-field, and it is the more necessary for me to do this inasmuch as in all the Government returns hitherto made, the quantity of the coal raised in the Bristol coal-field has been very much understated. The last return which was made put it at 630,000 tons a-year; but, after a very careful examination of the facts, and taking into account the quantity raised throughout the whole district, I am satisfied that the total quantity raised was not less than 950,000 tons last year; and this year very nearly 1,000,000 tons of coal will be raised in this small coal-field. There is one other point with respect to which I wish to make an observation. At the same time it bears rather more upon Mr. Greenwell's part of the subject than it does upon mine. It has been stated as very doubtful whether coal will be found on the south side of the Mendip Hills. There is a very well-defined anticlinal axis there, and there is no geological reason whatever why coal should not be found on that side of the Mendips. This [pointing the spot out on the plan] is a part of the mountain limestone, and the magnesian limestone is developed south of that. For my own part, I certainly do not see any geological reason why coal should not be found south of these hills, and of course it would be very important to know what the district extending in the direction of Glastonbury contains.

Mr. GREENWELL—On that point I may mention, that in the "Geological Society's Transactions" for 1824, both Mr. Buckland and Mr. Conybeare suggest the idea of a coal-field to be found south of the Mendips, and that opinion has subsequently been repeated by Mr. Conybeare and Mr. Phillips. I have examined the country on the south side of the Mendip range myself, and I have observed that south of the limestone there is a band of millstone grit, which extends right up to the southern range of the hills. I have examined the country for about two miles in that direction, and can bear testimony to the coming in of the millstone grit again on the southern side of that anticlinal axis. There are two points mentioned in the paper which I have read to the meeting, upon which I should be glad if some dissussion took place. The first is, with reference to the depth at which coal mines can be profitably worked. I have mentioned the depth of 400 fathoms, and I should like to hear the opinion of gentlemen as to the possibility of working coal mines at a greater depth than that; and the next point is, as to the possibility of ventilating the mines by means of ascensional ventilation, so as not to have the return current of air which comes out of the top side of the working sent back again to the deep. It is a matter of great importance to ascertain whether the return current of air could not be carried off at the upper part of the mine by means of ascensional ventilation.

The PRESIDENT—I should be very glad to hear any observations which gentlemen may be pleased to make with regard to these important papers on the coal-fields of Somersetshire. I do not know whether I understood Mr. Greenwell correctly as stating that some of the slip dykes of that coal-field passed through the lias limestone as well as through the coal measures.

Mr. GREENWELL—Some of them are said to do so, but others do not. At Radstock, a ninety-fathom dyke of the coal measures does not pass through the lias. I do not know of any instance in Somersetshire where there is a dyke affecting both the coal measures and the upper formations as well. I do not know that of my own observation, but upon referring to a paper, which must be taken as a statement of facts (I mean the paper contributed to the "Geological Transactions" by Messrs. Buckland and Conybeare), I find that they refer to some large faults which do affect both the formations. One thing I know, and that is, that at Radstock there is a ninety-fathom dyke, at the top of which the lias lies without the slightest disturbance. Most people know that a dyke of

ninety fathoms in the coal measures of the North of England affects both the red sandstone and the coal measures, because the dyke passes downwards.

The PRESIDENT—That is the reason why I asked the question. Of course, you see that if the dyke of the coal measures you allude to in Somersetshire passes through the lias and the magnesian limestone formation, that dyke must have occurred subsequently to the deposit of the magnesian limestone upon the coal measures, which it is very important to know.

Mr. GREENWELL—There are two descriptions of dyke there, one that occurred before the deposition of the upper strata, and another description of dyke which occurred subsequently. Both these dykes affect the coal measures, but one of them only influences the upper formations.

Mr. HANDEL COSSHAM—There is one great dyke that brings the top of the oolite, which is 600 feet thick, parallel with its base; but whether that affects the coal measures below has never been proved, because that part of the basin has not been worked.

Mr. ATKINSON—As regards the ninety-fathom dyke in the Newcastle coal-field, I am not convinced that the slip passes through the limestone at all, and think that the limestone may have been deposited against the slip of the dyke, after the dyke was formed.

Mr. GREENWELL—I do not very well see how?

Mr. ATKINSON—If you deposit limestone over an existing dyke, it would lie against the cheek or the side of the slip, unless the surface of the dislocated measures had been made level by denudation (or otherwise) after the formation of the dyke, and previous to the deposition of the limestone.

Mr. BOYD—Two or three gentlemen here are not quite satisfied as to the explanation which Mr. Greenwell has given of the overturn of the limestone, and they wish to know whether the coal seams turning over to the dip are portions of the same seams below. Perhaps Mr. Greenwell will give us some further explanations upon that point.

Mr. GREENWELL—I have got a plan here of a colliery in which it is shown that the coal was worked immediately under the mountain limestone, and people with whom I have spoken told me that they worked that coal. I can give no explanation of it, but merely state the fact. We must take the plan and the testimony together, and we can have no doubt in our minds that the fact has been correctly stated.

Mr. Boyd—I suppose it is not another limestone overlying another coal measure. We wish to know whether it is the same limestone and the same coal measure?

Mr. Greenwell—I simply state the fact. As I said before I cannot explain it.

Mr. Handel Cossham—There is a very peculiar instance in our district, in which the millstone grit has been tumbled over and thrown into a crevice. It occurs in the case of the Clifton rocks, and the section can be seen by reference to plan No. 2.

The thanks of the meeting were given to Mr. Cossham and Mr. Greenwell.

ON

THE PROGRESS OF COAL MINING

IN THE

COUNTIES OF DERBY AND NOTTINGHAM,

WITH

A BRIEF ACCOUNT OF THE MODE OF WORKING BY "LONG WALL."

By J. T. WOODHOUSE, Derby.

Before entering particularly into the subjects proposed to be treated of in this paper, it is desirable that some notice should be taken of the geological features of the coal-field.

A short account of the progress of coal mining in the district, together with a description of the method of working by "long wall," will also be dealt with.

The remarks on the first part of the subject, viz., the "Geology of the Coal-field," will have a special reference to the workable seams of coal, and the more important rakes of ironstone, but it is not proposed to enter into any detailed account of these latter, except so far as may be necessary for the sake of description.

The general position and thickness of the various beds of coal, and rakes of ironstone, is shown in the section made to accompany this paper.

The map represents the principal features of the coal-field, and part of the neighbouring county of York.

It will be observed that all the more important ironworks and collieries are enumerated, as also the railways, canals, rivers, &c.

The outcrops of the more important beds of coal, and the lines of known main faults, are also marked.

The neutral tinted portions represent the more immediate part properly

called the Derbyshire and Nottinghamshire coal-field: although the field extends northwards into Yorkshire; and eastward, dipping under the new red sandstone formation, to an extent not yet ascertained.

It will be seen that the coal measures are developed on the surface up to the line of the magnesian limestone: on the south it is terminated by an immense mass of conglomerated drift, which rests upon what was formerly the surface of the country, with the coal seams outcropping to the south-east, and the new red sandstone formation: and on the west, the millstone grit, or Farewell Rock of South Wales, and the carboniferous limestone are developed: whilst, on the north, there is a continuation into Yorkshire of the coal measures.

It will much simplify and explain these remarks, if attention is directed from time to time to the map and section.

The first seam of coal worthy of notice is called, in Derbyshire, the yard coal: the same in Yorkshire is called the wath-wood.

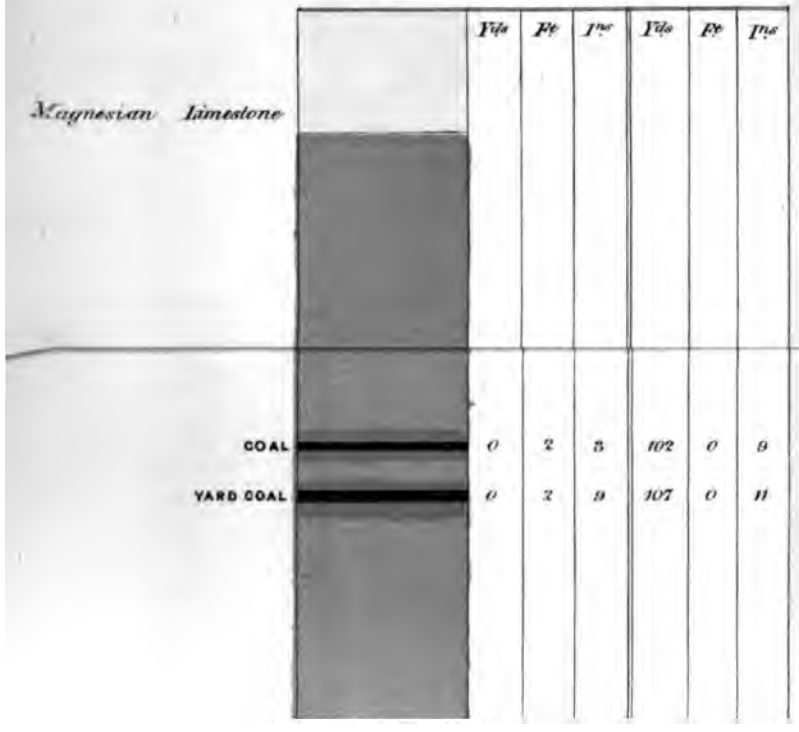
The next important seam is that known as the top or main hard coal. This coal has been worked in every locality where it has been found. Recently it has been sunk to at the Shireoaks Colliery, at a depth of more than 500 yards. It has also been worked at the following collieries:—Cinderhill, Portland, Swanwick, Duckmanton, Staveley, Eckington, Woodhouse Mill, &c., &c. (See map.) At Staveley, where it has been very extensively worked by Mr. Barrow, it appears to have attained its maximum of thickness. The thickness of the coal is given as taken by actual measurement. The hard coal of this seam is highly prized for furnaces, locomotives, and other similar purposes.

At Staveley, a few yards above the top hard seam, a bed of ironstone occurs, called the measure and balls rake. It has been worked extensively by Mr. Barrow, and used by him in the manufacture of iron; it may, however, be considered as a local formation, not being generally found productive.

About thirty yards below the main or top hard seam, the Duns-hill or Dunsil seam of coal occurs. This, however, does not warrant any detailed notice, as it has only been proved of good quality in one or two places. It has been principally worked at Swanwick and Duns-hill, and takes its name from the latter place.

The next seam of coal worthy of notice is called the Waterloo. It generally consists of three distinct beds of coal, separated by partings of bat and dirt. (See section.) This seam, like the former, has been worked only to a very limited extent.

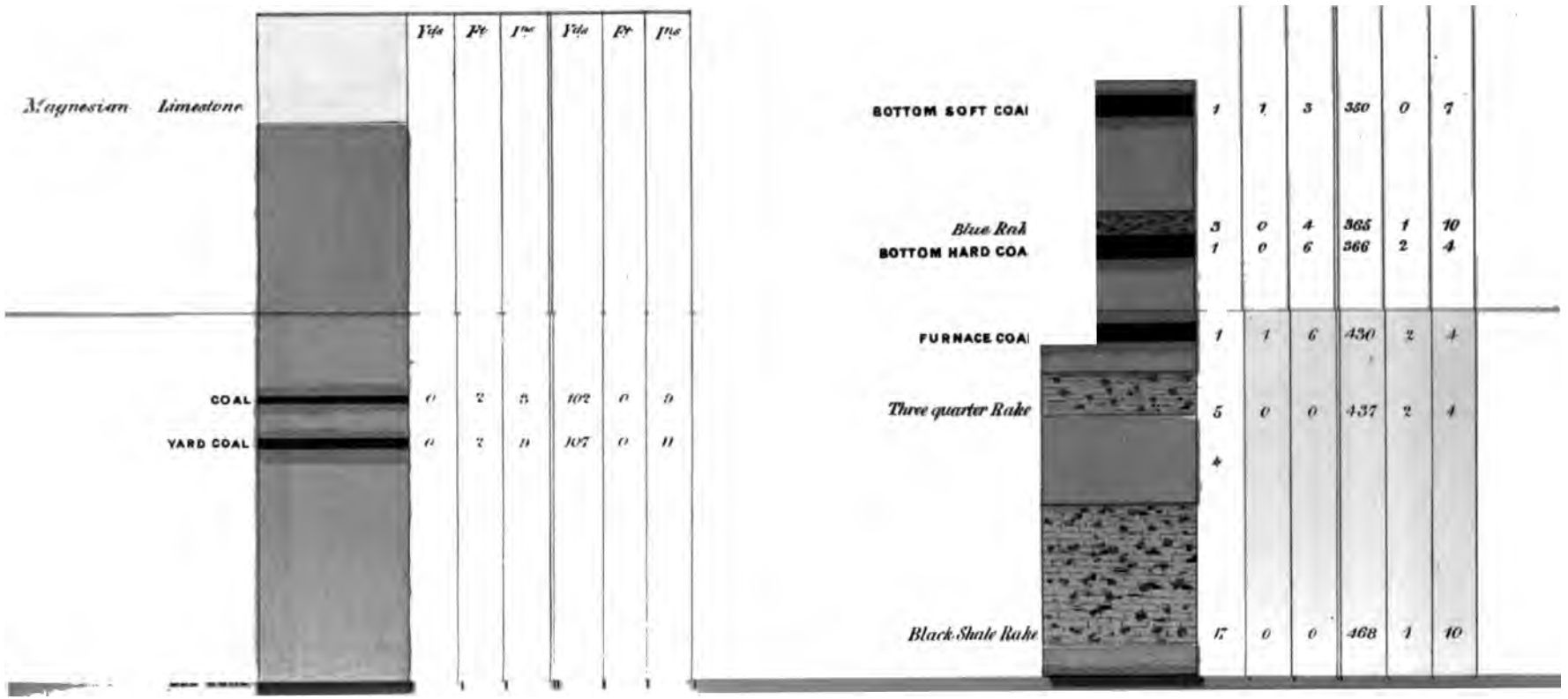
Section of the Strata of the Derbyshire Coal Field.



	Yds	Ft	Ins	Yds	Ft	Ins
COAL	0	2	3	102	0	9
YARD COAL	0	2	9	107	0	11

BOTTOM SOFT COAL	1	1	3	350	0	7
Blue Rake	3	0	4	365	1	10
BOTTOM HARD COAL	1	0	6	366	2	4
FURNACE COAL	1	1	6	430	2	4
Three quarter Rake	5	0	0	437	2	4
	4					
Black Shale Rake	17	0	0	468	1	10

Section of the Strata of the Derbyshire Coal Field.



Between the Waterloo seam of coal and the next workable seam called the main or bottom soft, two or three rakes of ironstone are found. The two most important are known as the brown and black rakes. These have been principally worked in the Erewash Valley district, and extensively at Staveley. There are other rakes of ironstone—the poor rake and the buff and cement rake, which occur at short distances above the brown and black rakes.

The bottom or main soft seam of coal is the next seam of importance. This lies at an average depth of 160 yards below the top hard coal. It has been chiefly worked at Trowell, Babbington, Shipley, Butterley, Staveley, and Pinxton. It is principally used for household and similar purposes, where a bright soft coal is required. Its average thickness is about five feet.

Between the main soft and bottom hard seams one rake of ironstone occurs, viz., the blue rake, which, together with the measure in which it is found, forms the roof of the latter bed of coal. The bottom hard seam lies at a depth of sixteen yards below the main soft seam. It generally occurs about three feet six inches thick. (See section.) It has been principally worked at the Kimberley, Shipley, Highfield, Marehay, Denby, Langley, Birchwood, and Pinxton Collieries. This seam affords a large proportion of hard coal. The hard portion is used in furnaces, in the manufacture of iron, and as fuel for locomotives and similar purposes.

The piper seam lies generally at a depth of fourteen yards below the bottom hard seam. The furnace seam of coal lies about forty yards below the piper seam, and two or three rakes of ironstone occur in the intervening strata, called the dogtooth and three-quarters rakes. The furnace seam of coal is about four feet six inches thick; the coal is bright and brittle, breaking up into cubical pieces. It has been principally worked at Morley Park, Oakerthorpe, and Wingerworth Collieries, and used in the manufacture of iron.

The black-shale or clod coal lies forty yards below the furnace coal. In the intermediate strata, the richest and most valuable bed of ironstone of the coal-field is found, taking its name from this seam of coal, and the strata in which it is found is called the black shale rake. It is found in its greatest perfection and value in the neighbourhood of Chesterfield, where it has been extensively worked at Clay Cross, Staveley, Hady, Wingerworth, Newbold, Whittington, and Unston. It contains on the average about three feet six inches of ironstone in about thirty feet of dirt.

The clod or black-shale seam of coal averages about four feet six inches in thickness; it is soft and bright, and is principally devoted to household and similar purposes, and is now sent in large quantities to London. Between this and the next seam of coal, the Buckland Hollow, or Kilbourne, there is a thickness of strata amounting to 160 yards. Many rakes of ironstone occur, which have been principally developed and worked at Denby and Morley Park. It will suffice if the names of the various rakes be given. They are as follow: — The Honeycroft is in about fifteen feet of ground (immediately beneath the Kilbourne coal), but between the black shale and Kilbourne are the Holly Close, Green Close, Bacon Flitch, Yew Tree, and other rakes.

The Buckland Hollow or Kilbourne coal may be considered as the lowest workable seam in Derbyshire, although seams of coal do occur above the millstone grit, one of which, the Gannister, has been worked. The Kilbourne seam has a thickness of about four feet six inches. It is used for household purposes entirely, and its quality is most excellent.

The collieries on the Kilbourne coal are Kilbourne, Denby, Morley Park, Buckland Hollow, and Stanton. There are three rakes of ironstone below the Kilbourne seam, called respectively the Honeycroft, Dale Moor, and Civilly rakes. The working of these has been almost solely restricted to Stanton.

Having thus noticed the geological features of the coal-field generally, the next part of the subject of the paper which claims attention is the progress of mining in the coal-field antecedent to 1826.

For the purpose of convenience and harmony with facts themselves, this account of the progress of coal mining in Derbyshire and Nottinghamshire may be divided into two parts; the first relative to the period antecedent to 1826, and the second relative to the period subsequent to 1826, and included between the years 1826 and 1861.

Up to 1790, operations were upon a most limited scale, being confined to horse-gins, rolls worked by men for raising coal, and sough adits, and day-levels for drainage. Chain pumps were also used, and windmills were applied as the working power.

The markets were, for want of communication, limited, being confined to consumption in iron-works at places in the vicinity of the coal-works, house fire, and in manufactories; also in towns (as in the instance of Sheffield and Rotherham) when near upon the coal-field.

Previously to 1790, charcoal furnaces existed in Derbyshire; one at Wingerworth was blown by a water wheel until about 1784. There are

many remains of these old charcoal furnaces, which can still be seen—some of them in very perfect condition—at Alderwasley, Cinderhill, Wingerworth Toad Holes, Denby, Heanor, Whaley, &c.; but, by the year 1806, they had so far decreased in number and use throughout the country, that only eleven were found at work that year. (See Farey's Derbyshire.)

Forges were in operation at Alderwasley, Brampton, Codnor Park, Killamarsh, Makeney, and Staveley.

Foundries existed at Alderwasley, Butterley, Chesterfield, Morley Park, Renishaw, Somercotes, and Wingerworth.

Coal was conveyed into the more remote districts in the rough horse-wains of the time, and carried also in sacks or creels slung on the backs of pack horses. Such being the demand, it is not surprising that the produce was upon a limited scale.

Immediately after that period, a great impulse was given by the construction of canals or channels of inland communication. Those lines affecting the district were, the River Dun or Don Navigation, leading from Sheffield into the Rother, and thence into the Ouse and Humber. The Chesterfield Canal, leading to the Trent at Stockwith, the Cromford, Erewash and Nottingham Canals, all communicating with the Trent and Soar Navigation, and extending by the Loughborough Canal to Leicester, and by the Union Canal to the Grand Junction Canal, and so to the southern and south-eastern markets. The Nottingham Canal, leading to Newark by the Trent, and so into the water communication in Lincolnshire, and also the Peak Forest Canal in the north of Derbyshire.

The only lines of railway in Derbyshire at this time were those in connection with the canals. In 1790 or thereabouts, there were wooden railways to the canals in use at Gresley, Pinxton, and Measham Collieries. The Erewash Canal was finished in the year 1793; Mr. William Jessopp being the engineer.

After these arterial communications were constructed, coal works were rapidly opened. In the district, the attention of capitalists was directed to the importance of the subject, and mining enterprise was making slow but certain progress.

The same seams of coal are at work at the present time as were in 1826, or immediately before (that being a period of depression).

Furnaces were in blast in 1806 at Butterley and Codnor Park, Riddings, Morley Park, Duckmanton, Calow, Brampton, Staveley, Renishaw,

Wingerworth, and Chesterfield. In 1806, there were twelve furnaces in blast, and six out; the total produce being about 10,329 tons per annum. The first blowing engine was erected at Morley Park about the year 1750. The large works at the Holmes, and others farther north, are not included, because they are in the county of York.

The machinery in use at most of the works was of an old description. For drawing coal and pumping, the atmospheric engine, which is simple in construction, and easily moved, was adopted. These were suitable for shallow depths, the pits, in most instances, not exceeding 100 yards; but there were instances where a better form of winding was adopted, in the double-acting engine of Bolton and Watt, for drawing, and the three-valved engine of the same firm, for pumping.

Railways, as a communication between remote parts of private undertakings, and in connection with canals, also began to make their appearance, not upon the gauge as at present adopted, but upon such a gauge as met the requirement or taste of the owners of the works for the time.

Of the quantity of coal produced at this period, no authentic account exists, excepting that the amount received up the canals in the Erewash district may be taken at 500,000 tons per annum; and the consumption, for manufacturing purposes, house fires, and in iron furnaces, at about the same amount.

Such was the state of matters anterior to 1827; and, with a slight additional impetus, they remained so until 1832.

The ventilation of collieries at this period was in a very rude condition, being all "natural." Furnaces and mechanical appliances were not understood, excepting to the extent of producing a current, by throwing back the water at the pump-head in the engine pit, and driving the air into the workings. It was no uncommon thing for the collieries of that period to cease working for days together, being charged with carbonic acid; and when carburetted hydrogen was found, frequent explosions took place—not upon the scale which has been witnessed in the South Yorkshire district, and in Northumberland, but a constant recurrence of small disasters. Their extent was limited, from the fact of a large quantity of carbonic acid gas being mixed with the hydrogen, which rendered the mixture not very explosive. The writer has frequently seen, in a face of six feet in height, the atmosphere at the firing point at the roof, and the candle extinguished by carbonic acid near the floor.

Before commencing upon the progress made since 1832, it may be

well to notice briefly the outlet or vend, and the way in which these outlets for coal were affected by the physical contour of the country.

Referring to the map, and commencing with Dronfield: the coal was taken to Sheffield in carts, as it is to this day. A railway has been projected, but at present nothing is done. It is the quality of the coal, and the coke made from it, which is used for manufacturing steel and Sheffield wares, which makes it so valuable.

On the east side of Sheffield, the produce of the mines was taken down the Don navigation, and so to the Humber, as has been described in a former part of this paper.

Passing south, the country rises gradually all the way to Clay Cross, and here the Chesterfield Canal was the principal outlet for coal to the east, as well as for castings, or the production of the iron-works of the district. The cost of conveying the minerals over land being so great as to be prohibitory; hence it was that, until the opening of railways, no coal found its way south from the district of Chesterfield, excepting what was worked immediately upon the Clay Cross ridge. After passing Clay Cross, the country falls to the south and south-west, as a reference to the map will show.

The produce of the Erewash Valley was taken south and east along the canals referred to in a former part of this paper; and out of the Ripley Valley along the Derby Canal to Derby, and westwardly.

The small offshoot of the Leicestershire Coal-field, running into Derbyshire at Church Gresley, had not any outlet of communication before the year 1828, when a tramroad was laid down to the Ashby-de-la-Zouch Canal.

Of the produce at this period it is most difficult to speak. Tupman, in his tables, gives the following statistics.

In 1808, according to Tupman's tables, the number of canal boats on these canals was 430 wide boats and 60 narrow ones. From June, 1807, to 1808, 8286 boat loads of coals passed on the Cromford, Erewash, and Nottingham canals, the aggregate weight being—

	Tons.
Hard coals - - - - - - -	205,006
Soft coals - - - - - - -	37,289
Cobbles - - - - - - - -	27,161
Cokes, about - - - - -	304
	269,760

But this leaves out the produce of the northern district, and coal sold on

the Chesterfield Canal and on the Derby Canal, and it is not easy to obtain access to documents detailing these facts, if, indeed, any exist.

In 1830 the whole produce may probably be taken at one million tons. It may also here be noticed that at that period hot blast air was not introduced into the manufacture of pig iron. It has since doubled the make, and much increased the consumption of coal.

In 1832 a great change came over the district. The Liverpool and Manchester Railway was completed, and other lines began to be talked of. The Leicester and Swannington Railway, in the county of Leicester, was projected, and partially opened; and the Midland Counties and other lines were before the public.

It was not until 1836 that the great arterial lines were secured; those of the greatest importance, as through outlets, were then established.

The greatest impetus of all was given by the construction of the Erewash Valley line, obtained through the untiring energy of the late Mr. William Jessopp, one of the firm of the Butterley Company, who, combining the science of the engineer with the forethought and tact of the merchant, after delays and obstacles extending over years, succeeded in securing the line. It may not be uninteresting to know, that that line of railway is now being extended to Clay Cross, and will form part of the main line of the Midland Railway communication between London and the North.

Upon the opening of what is now the Midland Railway—but which at first was made up of several distinct companies—and upon the railway company, after some years' experience, adopting a moderate scale of tolls, an immense impetus was given to the vend of coal. As an instance, the Erewash Valley supplied into the general market about half a million tons of coal per annum. Since the railway was opened, in last year alone, upwards of 1,100,000 tons were sent down the railway, without materially affecting the traffic upon the canals.

Without going farther into these details, it may be well to state that the same increase has taken place (in fact, to a much larger extent) in the Chesterfield district, as well as in the Ripley Valley, now accommodated by a branch from the Midland.

This increased demand, in due course, called for an increased supply, and accordingly a large number of new collieries were opened, and old ones improved and extended. Take as an example, the Shipley Colliery. At the early period of 1832, 30,000 or 40,000 tons was the annual vend; now it is nearly, or rather quite, four-fold. The machinery at the colliery

was of comparatively old description; the engines being all upon the condensing principle; the tram plates cast iron; no slides; no ventilating furnace, &c. Now, the engines, with one exception, are high-pressure; the pits are provided with slides; all the roads are laid with wrought iron rails; the ventilation is by three powerful furnaces; and every modern means and appliance is adopted to ensure safety and economy. In the hard coal, which is subject to sudden outbursts of gas, safety-lamps are used exclusively. Apropos of slides, it ought to be known that wood slides of precisely the same description as those used at present, were adopted at Duckmanton Colliery, near Chesterfield, in 1825, by the late Mr. Charlton, who was a man of scientific attainments.

A general description of the Shipley Colliery will serve as an illustration of the mode of working by long wall; but there are one or two peculiarities in this colliery which are worth attention. Referring to the meridian line upon the plan, it will be seen that the grain of the coal trends nearly north-west, and the polarity or northern streak is the same in both seams. By comparing the two plans, it will be seen that the direction of working is at right angles; in other words, the workings in the hard coal are upon the face or bord of the coal, whilst those of the soft are upon the end. This mode of working upon the end was adopted to produce a larger quantity of cubical shaped coal. The seam being tender, and full of face slines or partings, and long grained, much waste was caused by working it upon the face in the usual way, the constant crush or weight, which is so great a help in long wall working, breaking the coal into long thin pieces at the face. The writer estimates that twenty to thirty per cent. more large coal is produced by this mode. It was the competition in the London markets which first called attention to the subject.

An inspection of the soft coal plan will show some irregularity in the manner in which the works are laid out. This has arisen from the circumstance of the colliery being an old one and undersized. This seam produces a fair quantity of gas, which comes away regularly, varied a little by the rise and fall of the barometer. The principal part, after the management of the ventilation, is to see that the goaves and road-ends are regularly examined. As the roof falls rapidly, upon this system of working, no great accumulation of gas can collect in the goaves.

Upon referring to the hard coal plan, a very different arrangement will be observed. It will be seen that, from the pits Nos. 3 and 4, three headings were driven out direct on the end or headways course, a rib or

pillar being left some twenty-five yards thick on each side. The faces are opened off the flank or parallel heads, and the workings continued, the coal being brought out along roads made in the goaves, until they were terminated by faults.

This principle has been simply extended, and recently two more shafts have been opened at Nutbrook. The ventilation is of the most simple kind, the current running on the main road, and returning to the upcast along the faces. This pit is liable to heavy outbursts of gas, and some explosions have been the consequence. At present nothing has been discovered to indicate when these outbursts may be expected. They occur irrespective of faults, or of the state of the barometer, and proceed from both the roof and floor of the mine; but the latter is more subject to them.

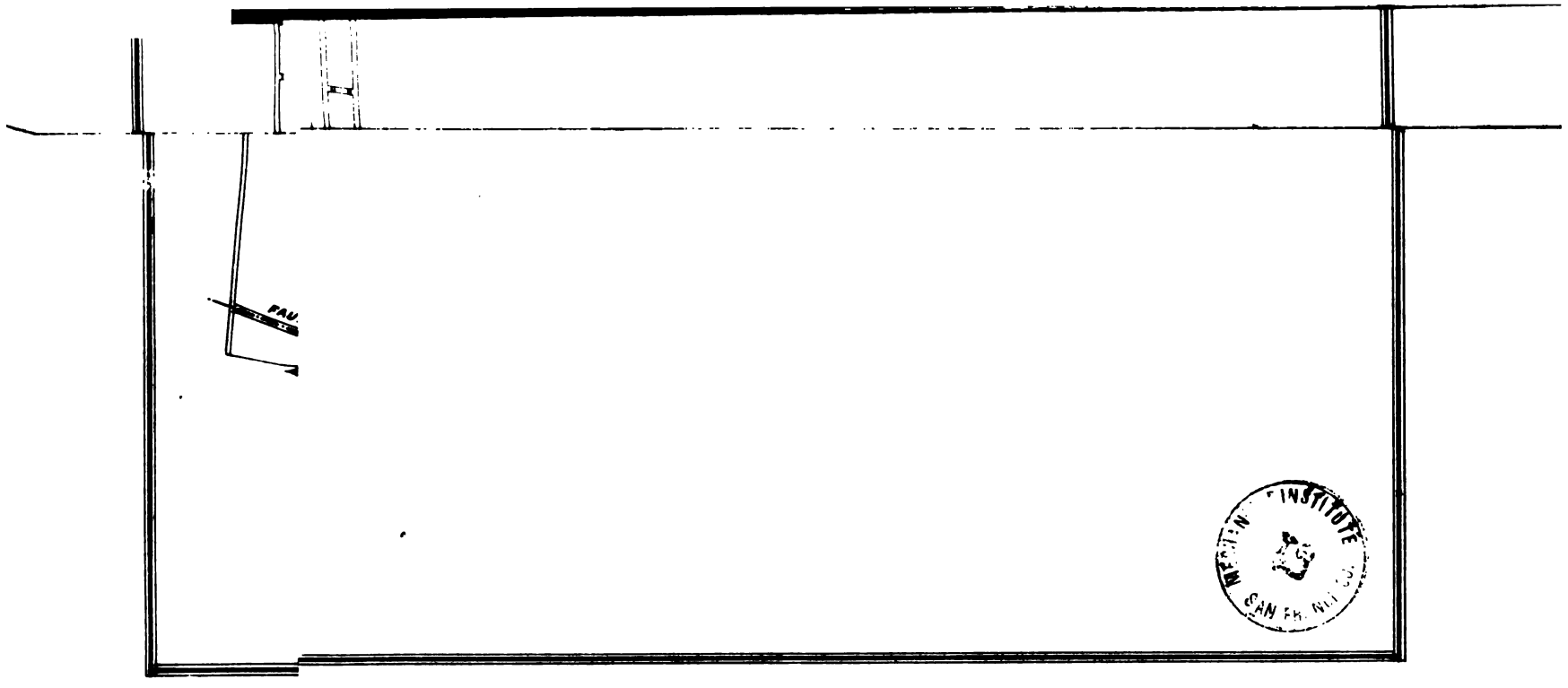
In the year 1850 an outburst of gas occurred in the floor of the east face. A large quantity of gas came out of the thill, or clunch, heaving it up in the manner of a rapid creep. The gas found its way to the furnace and fired there, killing the furnaceman, who was the only man in the pit at the time; smashed the doors and burst stoppings, but did not kill the horses.

No heavy outburst took place after this until 1857, when the gas fired at the candle of a hewer in the west face, killing two men and injuring two more; and in a few minutes afterwards, the disaster was aggravated by one of the workmen accidentally firing a quantity of powder.

At the inquest it was strongly urged by the Government Inspector, backed by the Coroner and jury, that safety-lamps should be exclusively used in the gates and bords. This was adopted, which, with the additional precaution of passing the air into the upcast by dumb drifts, and not through the furnace, has had the effect to the present time of remedying the evil.

Although three heavy outbursts of gas have occurred since that time, firing heavily in the lamps, no mischief has been done beyond alarming the workmen, and putting the underviewer on the alert. The lamps used are those on Stephenson's principle. For the care of them persons are appointed, and the men are not allowed to take them away from the works. The main point to be noticed, is the fact that the whole pit is frequently examined, in every place where gas could possibly be found, without any being discovered for months together, when suddenly a whole district becomes charged.

The observations which apply to Shipley Colliery are equally appli-


PAU

cable to many other collieries: all the most improved modes are here in use, and the writer is strongly disposed to think that, in certain particulars, the high tone of mining in the North of England is approached.

The writer is not prepared with full statistics, not having been able to secure them; but they will be furnished shortly. It may be mentioned, however, that the coal now consumed in iron works has reached 700,000 tons, and for locomotive purposes 250,000 tons per annum. The quantities sent to London are shown on the Coal Exchange returns. The inland consumption is rapidly increasing.

LONG WALL.

The mode hitherto adopted in working the mines of coal above described, with the exception of the black shale seam, is by long wall. It is the only method which has hitherto been found economical in labour, and productive in yield of per centage, from these mines.

In considering the subject, it must be constantly borne in mind that the seams are variable in quality, particularly the principal ones, and that difference entails a vast amount of hand-picking and cleaning at bank, as well as what is done by contract arrangement with the workmen in the pit. By variation of quality is meant a difference in the component parts of the seam—hard and soft parts alternating. It is, therefore, desirable to work the coal as large as possible, and to send it in that state to bank. The long wall system is peculiarly adapted to this state of things.

In the black-shale seam referred to, there is greater uniformity in the structure of the seam, and, with the exception of a band of very inferior coal and dirt running through the middle, which is not included, the quality is pretty uniform.

Two plans have been prepared to illustrate and explain this part of the subject, and it is considered very desirable that the plans should be those of some colliery which is really in work by the long wall, and not an ideal plan. The plans are those of the Shipley Colliery (before mentioned), the property of A. M. Mundy, Esq., of Shipley, and the workings are those of the bottom hard and main soft coals. (See diagram.)

For the purpose of simplifying the arrangement of the subject, it will be well to divide it as follows:—

1st.—As to the method of working.

2nd.—The conditions under which the long wall system can be adopted.

3rd.—In relation to ventilation.

4th.—Comparison of the long wall system with the pillar.

The method of working coal seams by the long wall system is exceedingly simple, and may be described in general terms as follows:—Two or more parallel levels are driven from the pit, for main roads, opening heads, water levels, and returns, as the case may be. From the main road, at a convenient distance from the pit, and at suitable intervals from each other, gates are driven on the rise, and, after a certain distance has been left solid for the support of the main road, workings are commenced. The banks or faces average a width of 80 to 400 or 500 yards; the length, however, is, of course, much influenced by the quality of the roof, the nature of the floor or thill, and the quantity of coal to be drawn.

The working is thus done:—A set of hewers, called holers, proceed generally during the night, to cut away or undermine the face of the coal, usually to the extent of about a yard back, and averaging about six inches high. Small pieces of wood, called sprags, are inserted between the coal and the floor, at places where it appears probable that the coal may fall, after it is undermined. At the cutting end, or end of the face, the hewers make a vertical nick at right angles with that under the coal. This operation having been performed, another set of men proceed to take the coal down, by driving wedges into the face, or by the use of powder. By this means, large blocks of coal are obtained, which are then broken up into smaller pieces, and, being placed in corves, are conveyed from the face of work to the pit, and thence to the surface, as in ordinary working. Lastly, after the coal has been removed from the face, the packers come in, whose duty it is to keep the bank and goaf roads and faces well timbered and secure. At short distances (according to the strength of the roof) from the face, they erect props, putting a flat piece at the top between the props and the roof. When there is a good roof, it is generally necessary merely to advance the same props, care being taken to place them opposite to the intervals or spaces between the props in their former position. When, however, there is a bad roof, it becomes necessary to place puncheons more frequently and nearer together, or else to build piles of wood or stone. Iron props are much used. The coal having been thus got, the smaller coal and refuse together are thrown behind, and fill up the space called the goaf, and the roof breaking in, a solid compact mass is formed.

This minute description of working may appear to be unnecessary, as almost all persons connected in any way with collieries are conversant

with hewing coal; but the long wall system, well carried out, differs so materially in management, that it is necessary to call attention to the smallest details.

In most districts where the coal is cubical in structure, and pillar work is adopted, the hewing process is done in a very slovenly and indiscriminate manner, the colliers hacking and cutting in all directions, as the coal is comparatively tender; but in strong coals, worked in long wall, this cannot be done. The writer, however, is forced to admit one unpleasant fact, that long wall management is not nearly so good as it was in 1830. It has retrograded, and not advanced. This has been caused by a large importation into the mines of half-bred colliers, and too much haste to get out large quantities.

Where two or three seams are to be worked one after the other, the whole success of the undertaking depends on the soundness and good packing of the goaf. The main goaf roads are very often kept up by stone walls, called packs. The proper construction of these packs is of great importance.

The circumstances which are favourable to long wall working are, a good roof (that is, a hard broad stratum over the coal), and a hard stratum beneath the coal. Sometimes the holing is made in the middle of the seam, when a more convenient stratum is not found underneath; but this deteriorates the coals by breaking them up into small pieces.

Wherever, then, these desiderata are to be found, the long wall method is to be recommended, both on account of the simplicity of arrangement, the ease and efficiency of ventilation, and the economical manner in which the coal may be got.

The method of ventilation may be described in general terms, as the passing of an adequate current of air in a continuous stream along each bank, and which, entering at one end, passes out at the other through a short distance of generally goaf road, called the return air-course, to the upcast shaft. The main road is used as the main intake, and the air is distributed from this to the different banks. Stoppings and regulators are placed in different places where it is necessary to regulate and divert or split any air-current. When the seam is fiery, the return-air is carried to the upcast shaft by a drift, called the dumb drift, entering the pit a short distance above the furnace.

Such is the very simple mode of ventilation usually adopted in long work. Of course there are cases where necessity compels a modified plan; but that now stated may be considered the one generally in use.

Many modified forms of long wall working have been adopted in other districts, such as the long work of the Yorkshire Coal-field, in which the coal is worked in banks of various widths, separated from each other by thick pillars of coal, which are afterwards taken out by working back.

Another modification, called narrow bords and long work, is also adopted in the Yorkshire Coal-field. In this method, two narrow and parallel bords are driven, a pillar of coal of about thirty yards in width being left between each pair of bords. These having been driven the required distance, a communication is made between the pairs of bords, and the coal worked similar to long wall towards the pit. By this means the goaf is left behind, and there is no necessity for keeping it up by walls or packs.

The general mode of working having been described, the produce may now be noticed.

By a little consideration it will be seen, that as the supply to the shaft in pillar working is only limited by the number of bords open, so in long wall it is only limited by the length of faces open, and the number of gate roads open in such faces.

Taking a case where the coal lies tolerably level, as at Shipley, loaders will be at work at each side the gate; and as, under ordinary circumstances, where the coals are properly prepared for the loaders, by what is called turning the coals out, or splitting them up ready for the loaders, thirty tons per day will be sent from each side; each gate will produce sixty tons per day, which, multiplied by the number of gates, gives the quantity of coal which can be produced from each pit, assuming that engine power and other requisites are in proportion.

Of the comparative merits of the long wall and pillar system it is not difficult to decide. Supposing all the seams were of the same quality and structure, either one mode or the other would be adopted, without any question being raised as to its merits; but as the component parts of the roof and floor, or thill, vary in innumerable ways, the mode of working must be adapted to the circumstances.

Pillar working has many advantages, and long wall has its peculiarities; but the fact is, that either mode cannot be adopted at the pleasure or caprice of the viewer. Some seams, for instance the cubical in structure, are best worked on the pillar system; and, on the other hand, the long-grained, hard, splint coals, are best worked by long wall.

The conclusion is, that no general rule can be laid down. As in civil engineering, the true system is to adapt the means to the end to be

attained, so in coal mining, long wall or pillar working must be applied to meet the circumstances of the case.

Before concluding these remarks, the writer is desirous of calling the attention of the meeting to a matter which is well worth the notice of all parties interested in the management of fiery collieries. It is an invention by Mr. William Buxton, viewer at Springwell Colliery, Staveley (the property of Richard Barrow, Esq.), for ascertaining the quantity of air in the mine, and regulating the firing at the furnace.

The paper upon this subject was then read by Mr. Howard.

BUXTONS FURNA

BUXTON'S
VENTILATION REGISTER AND DETECTOR.

By W. F. HOWARD.

This instrument is intended to be used in the air-courses of mines, especially in coal mines, whatever be the ventilating power employed. It is most advantageously placed at the confluence of the main return air-courses near the upcast shaft, in view of the furnaceman, where the furnace is used. Its performance consists in—

1st.—The indication, by separate fingers upon one index face, of the quantity of air actually passing along each return at the time of observation.

2nd.—The registration, by separate pencils upon one register paper, of the quantity of air at any desired intervals throughout the day, or any longer period.

3rd.—Warning the furnaceman at any desired intervals to attend to the furnace.

4th.—The accumulation of proofs that the furnaceman has done his duty, or that any other official has been at the instrument at any required time.

5th.—The indication of the progress of time.

Consequently, the furnaceman is at all times cognizant of the state of the returns, and can regulate his fire accordingly. Also in the event of a sudden or considerable fall in the indications of any one return, he will send word to the ventilator, to examine into and remove the cause. The ventilator to examine into and remove the cause. The ventilator learns with certainty whether the furnacemen are attentive; he has also certain and speedy warning of any stoppage or diminution of the air-currents. The underviewer has the same information as the ventilator, and ensures the attendance of the latter each day at the furnace, to change the register papers, &c. The owners' property and the workmen's lives are rendered more secure, since the state of the pit is at all times communi-

able to apply a remedy in
papers should be entered
office, for the examination
and for production before a

as follows :—

moving parts to be enclosed in a locked
any number of (say three) main returns
of ascertained area in each return, is
upon a hinge, a sheet or vane of any
the best), having one of its surfaces
the wind. On the other side of the hinge
with the sheet, but in a contrary direction,
hair wire. The hair wire at its other extre-
the indicator box and over a pulley, is connected
and index finger sliding up and down a cylinder,
the greater the pressure upon the sheet, the higher
rise; and if the pressure decrease, the weight

fingers are always visible, side by side, through a glass
front of the indicator box, moving up or down three gra-
duated scales, the position of each finger showing upon its
of air in its return at the time of observation.

recording pencils pressed by the three weights, which are
little out of plumb, move in the same vertical plane,
right angles to, the surface of a vertical cylinder, on which
paper is being rolled. Each pencil's range upon the paper is
the vertical limits, and for each return a portion of the
is divided horizontally, in exact correspondence with one
the index face, from data obtained by repeated measurements of
of air current at the pressure sheet and simultaneous noting
corresponding, such divisions remaining correct so long as the area
in the air-course where the pressure sheet is fixed continues
Vertical lines upon the paper mark the intervals of time.

the moving power is the wind acting upon the three pressure
the three returns. To give periodical motion to the cylinder
the register paper, to ring the bell, to accumulate more proofs of
fireman's attention, and to show the approximate time, a small
of water is required. A portion of the water provided at all fur-
for wetting the slack, may be first used in working the instrument.

From the supply pipe water flows constantly or occasionally into the upper or reserve tank, and thence passes through a tap into the lower tank, in which a uniform head is maintained by means of a waste pipe. From the lower tank an adjusted tap admits the water into a trough with sloping bottom. At the deep end of the trough, and forming part of it, is a box with balance weights. The trough, when nearly full, overbalances, and working upon a horizontal axis, tips upon its shallow end. This end is covered, except a slit level with the top, through which the water escapes gradually, until the box of weights preponderates, when the trough returns to its former position.

The cylinder on which the register paper is rolled fits upon a square axle, projected upwards from the centre of a circular horizontal toothed metal plate (see peg plate), which is alternately pulled and pushed one tooth forward by two rods, one fixed upon each side of the tipping trough.

The ventilation register is now complete, and may obviously be adjusted to any intervals by means of the tap supplying the tipping trough.

When the register paper is full, the cylinder is to be removed, and a duplicate cylinder and paper supplied, the paper being fed from a box adjacent.

A finger, pointing to the time upon a dial, may be moved round by the peg plate, or a second tipping trough may be employed to supply the larger one, and to move the dial finger at shorter intervals.

A bell may also be rung by a projection from the tipping trough striking the bell lever.

The peg plate is fitted with numbered pegs, one of which comes to a slit in the box each time the bell rings, when the furnaceman is required to attend to the furnace, and at the same time to record proof of his attention, by taking out the peg and dropping it into a pegholder. Should he neglect, the missing peg betrays him, and the registering pencils may be expected to confirm the charge.

Either the registering paper or the pencils may be common or prepared, so that the result of an indelible mark is obtained.

This instrument is not patented. Its inventor is Mr. William Buxton, by whom it has been applied at Mr. Barrow's Springwell Colliery, Staveley, Derbyshire, of which he is the resident viewer, under Messrs. Woodhouse and Jeffcock, Derby.

DISCUSSION

ON

MR. WOODHOUSE'S PAPER ON THE DERBYSHIRE COAL-FIELD, AND THE METHOD OF WORKING COAL BY LONG WALL.

The PRESIDENT having announced that the meeting would proceed with the discussion,

Mr. WOODHOUSE said—Gentlemen, perhaps you will permit me to make a few preliminary observations upon the subject matter of the paper generally. I was requested, some time ago, by the Council of the Institute, to read a paper specially upon the system of long wall working, that description of working mines being a matter of great interest to our friends in the north, and, probably, not being so well understood as it is in the district which we are about to take into our consideration, or in South Staffordshire. In this district the greater part of the coal, with the exception of the very best coal, is all worked by long wall working, and, therefore, to offer any lengthened observations upon that subject would be, as regards the gentlemen of this neighbourhood, entirely out of place, and mere loss of time. Inasmuch, however, as the subject of working by long wall is exceedingly interesting to the gentlemen of the North of England, and looking to the fact that we are now assembled in Birmingham—having regard to the number of northern gentlemen who have come here—bearing in mind the attentions which we were led to believe that we should receive when we came here, and which have been so fully carried out by the kindness and hospitality which we have received at the hands of the gentlemen of this district, I have thought it better to compress my paper somewhat, confining it chiefly to the description of the Derbyshire Coal-field, and add a few remarks on long wall working. I may state that the map which you see before you embraces a part only of the coal-field. It is taken from the counties of Derby and Nottingham, and is bounded on the western side by the outcrop. A

little farther in this direction [explaining by the map], we come on the millstone grit and the carboniferous limestone—on this side by the magnesian limestone, which extends in this direction [pointing it out]. It extends northwards on this blue line, somewhere north of Leeds. Taking it altogether, it is about seventy-five miles. The map before you represents a distance of about forty miles, and does not comprise, by any means, the largest and most important part of the coal-field in the county of York. At present, I am only dealing with the counties of Derby and Nottingham.

The PRESIDENT said—I am sure every one present must be delighted by the able contribution with which Mr. Woodhouse has favoured us; and if any gentleman requires explanations with reference to particular points, I am quite sure that that gentleman will be happy to give you any further information which you may desire, either with reference to the long wall working, or the description of the coal-field to which the paper refers.

Mr. POTTER—With reference to the long wall system of working, I should like to ask Mr. Woodhouse whether he finds it more advantageous to work to the rise or the dip of the mine?

Mr. WOODHOUSE—In working the long wall, it is found more advantageous to work to the rise of the mine than it is to work to the dip; that is to say, the workings are carried on from the dip to the rise. There are many instances in these districts where the roads are driven right away down to the dip, but the coal is universally worked, as far as it is possible to do so, on what we call a rising face. In this system of long wall working, one of the principal things to be secured is a continual pressure from the roof, which, in pillar working, as you know, is not necessary or usual. But in long wall working it is absolutely necessary to have that continual pressure, and therefore it is that the coals should be undermined, or holed, or curved, according to the requirements of the particular district, in some instances before they are taken down, whether they are taken down by powder or by working. I think it is very important that the coals should be undermined for a considerable time. It often happens that, after the coal has been undermined ten or twelve hours, when the hewers go down and knock away the spragg or supports which have been left during the process of undermining, the coal comes down of itself in a mass; whereas, if it is not allowed to rest some time after undermining or holing, not only will great extra trouble and exertion be required to get the coal, but it will come down in very small

pieces, the consequence of which will be, that a very much larger per centage of small coal will be made. In working on the dip face, there is always an inconvenience arising from having the pressure of the roof downwards on the face of the coal, the tendency of which is, that the coal falls down on the face, thereby producing a larger quantity of small coal, besides which, the hewer has all the inconvenience of having continually to cast back the rubbish into the goaf or waste.

Mr. DARLINGTON—There is a question I should like to ask Mr. Woodhouse, which is of considerable importance, and which, as he has not referred to it, he will kindly excuse my mentioning. It is, whether either of the seams shown on the two plans are subject to spontaneous combustion; and if so, whether they were liable to any great extent?

Mr. WOODHOUSE—The seams referred to in the plan are not liable to spontaneous combustion. I have known the Shipley Colliery for many years, and several other collieries working the same seams, and I have hardly known an instance of spontaneous combustion. There are, I believe, some instances in which spontaneous combustion has occurred. There will, however, be a paper read upon spontaneous combustion in respect to one part of the county not referred to here. It applies more particularly to the Lancashire coal-field, and not to the Derbyshire. When that paper comes on for discussion, gentlemen will have an opportunity of considering the whole question of spontaneous combustion, and I have no doubt it will prove a very interesting topic.

Mr. GREENWELL—With reference to the plan of the two workings exhibited by Mr. Woodhouse, I observe that in one of them there are forty-four doors, and in the other forty-three, arising from the want of splitting the air. I also understood, if I gathered Mr. Woodhouse's observations correctly, that there is some gas made in these mines, and consequently the air from any of the places in which the gas may be made, must necessarily pass from that to the next place. I wish to know whether it is the practice in this colliery to work by naked candles or by safety-lamps?

Mr. WOODHOUSE—In one part of the mine, where the soft coals are obtained, it is customary to work by the light of naked candles, but in other portions of the mine the men work exclusively with the safety-lamp.

Mr. GREENWELL—I merely made the observation in consequence of the want of splitting the air, and the number of doors that are necessary.

Mr. WOODHOUSE—The reason for having that number of doors is this. It is found that in the goaf roads there is a natural tendency for them to become warm. The roads are perfectly dry, and from the circumstance of men and horses constantly passing along them with lights, it is necessary to have a small split of air running through them. There is no gas made in the working, and the effect of the air passing along them is to completely drain the stratification of gas. The gas is only in the face, and there have been no instances, that I am aware of, in which there has been any gas in the roads, which is very curious. It is obvious that we must have a large number of doors in every cutting to prevent the return air current running into them up one side and down the other, which would be very inconvenient.

Mr. GREENWELL—It is a simple matter of cost, I suppose, as to whether it is more expensive to have a return air current coming down from different portions of the workings, or to keep so many doors for the purpose of diverting it?

Mr. WOODHOUSE—I know, as a matter of experience, that it is very undesirable to bring any return air current upon roads through which men and horses are continually travelling. The object is to have a simple split running from the main road inbye, so that no return air shall come down any road where the people are at work. I think if you will examine the map closely, you will see that no return air can come down any working road.

Mr. GREENWELL—There would not be any return air current if the air were split off and came along a separate air-course, not by the working road, but by a separate return air-course?

Mr. WOODHOUSE—That is just the whole question, and I may say it is the difficulty with which we have to deal in working a coal mine by the long wall system, because you must either make a separate return air-course, leaving a solid piece of coal for that purpose, or adopt the system of having a large number of doors. Now, as far as the economical working of the mine is concerned, we cannot possibly leave pillars at all. The cost of working that coal is very great indeed, from its extreme hardness, and to leave a number of pillars would greatly increase the cost of hewing and cutting away, besides losing the coal itself, because you must recollect that the coal once left in the mine is lost for ever. In Yorkshire, the system which they follow is what they call the bord-gate pillar system, which means simply that pillars of coal are left on one side of the main road; where pillars can be left with advantage, you can

introduce as many splits of air as you please, but that is not so in this case, and then you may do away with the doors, for I am quite willing to admit that where they can be done without, the system of working by doors is a most objectionable system, and wherever they can be done away with, they ought to be; but where the coal must come out whether or no, and pillars cannot be left, I do not see very well how we can do without doors, without having a return air-course down the roads.

Mr. SPARROW—Is not the cost of working a mine by means of these long goaf roads very great?

Mr. WOODHOUSE—The working of these roads is of a very peculiar description, and is very well worthy of some notice. These workings are all made by contract. Perhaps five, six, or seven men take a contract for each of those spaces [pointing them out on the map], which are locally called a gate. The hewers hew the coal, lead it out to the face of the working, and bring it a certain way down the roads, say from here to here [referring to the plan], which represents 100 yards. This work is done at so much per ton, not at so much a score. The contract price includes the formation of these roads in the first instance, the ripping of the roof to make the height after the subsidence takes place, for the subsidence follows very shortly after the getting of the coal, and roads which were originally three feet six inches or four feet high, by the time they have cut ten yards or so, will be much lower, the roof of the goaf will probably be reduced to two feet. That renders necessary the ripping of the roof, and the waste which is taken away from the roof is packed away on each side so as to form a face or support for the goaf, and so they proceed. All that forms a part of the contract price, and after that another contract is made for the purpose of bringing the coal to the shaft after its having been passed along certain portions of the workings here [pointing to the plan], at distances I have named, by the men who keep the roof and goaf in order. All this work is done at so much per ton in our part of the world, for we do not adopt the plan of paying by the score, although no doubt that in those cases where the coal is all of one quality, the plan of paying by the score is very much better. It is necessary, however, in our case, to separate the inferior part of the coal from the best part, and by our system the best part only is to be paid for, therefore we adopt the system of paying by the ton in preference to paying by the score.

Mr. BASSETT—I think it would be interesting to the members of the Institution, if Mr. Woodhouse will kindly inform us what is the actual yield per acre, per foot deep, of a seam of coal worked on this system?

Mr. WOODHOUSE—The yield per acre of this colliery is small. I am speaking, of course, of the yield of the better quality of soft coal.

Mr. BASSETT—What I should like to know, is, what proportion the coal got and vended, bears to that lost in the mine.

Mr. WOODHOUSE—Perhaps the better way would be to give you the yield by the vend. The custom in this colliery is, after the coal is sorted, to set aside a portion of the coal first of all for the use of the colliery itself, such as coal for the enginemen for the general establishment, for the workmen above, for the colliers, in point of fact, for every imaginable person who can by any chance have a claim upon the coal. The next thing is, to set aside the coal required for the locomotives and anything of that sort; and when all that has been taken out, we have not got a yield of more than 1000 tons per acre of one foot thick, the ton being reckoned at the rate of 21 cwts., and the one cwt. at 120lbs. The specific gravity of the hard coal may be taken at about 80lbs. per cubic foot, and of the soft coal 78lbs. per cubic foot. Having got the yield per acre, it is not difficult to ascertain the rate.

Mr. COSSHAM—I should be very glad if Mr. Woodhouse would inform us whether he has seen, under similar circumstances, the pillar and stall system tried, and whether there is any great difference in the proportion of the accidents that occur in each?

Mr. WOODHOUSE—With respect to the question of accidents, there can be no doubt about it whatever, that from the circumstance to which I have alluded with respect to continual pressure being a necessary element in working the long wall system well, we are more subject to accidents from falls in the long wall system of working than in the pillar and stall working. There can be no question about that, and when safety-lamps were first introduced into that colliery, there were great objections raised to their use, on behalf of the men, on account of the light being so diminished that they could not see the insecure places in the roof, and take the same precautions against falls which they did previously. Indeed, it was only upon the urgent representation of the Government Inspector, in consequence of an accident which occurred, and which I described just now, that the managers of the mine were able to introduce the safety-lamps. Had it not been for that accident, we never should have succeeded in establishing the system. There can be no doubt that the light of a candle is vastly more convenient than the light from an ordinary safety-lamp. We commenced with the Davy-lamp, but we could not get on at all with that; we then tried to get an efficient supply of the Stephenson-lamps, but we could not procure them.

We sent to Newcastle for all the lamps which we could possibly lay hold of, but we could not get enough of them for some time. Such, however, is the effect of habit, that the lamp having been introduced and become thoroughly established, I now think that the men would be very unwilling indeed to give up the Stephenson-lamp. They say that it gives as much light as they require, and they do not have to pay for any oil, which is a great consideration with them, and they used formerly to have to pay for candles. There is a pretty free current of wind there; only a limited portion of the waste is thrown, and there are only small splits of air to the extent of from 2000 to 3000 feet going up every gate, therefore there is a pretty free current of air going up these roads, so that you could not carry a candle without a lantern. That current of air would render the use of the Davy-lamp extremely inconvenient, for one of the greatest imperfections of this lamp is, that it is continually smoking the gauze if there is the least current, whereas the glass of the Stephenson-lamp operates as a complete shade, and most effectually prevents that difficulty; the result is, that not only do the men greatly prefer using the Stephenson-lamp, but that practically it is almost impossible in this and similar collieries to work with any other.

Mr. Cossham—Then, I suppose, that although the accidents from falls may be more frequent in collieries worked by the long wall system, the accidents which in other mines are continually arising from other causes are less?

Mr. Woodhouse—There can be no doubt that the adoption of safety-lamps in this, as well as in other mines, has been the means of preserving many lives.

Mr. Handel Cossham—On the long wall system I mean. I am speaking of mines which are worked exclusively on that system.

Mr. Woodhouse—In this very colliery the first explosion took place at this spot in the goaf [pointing out the spot on the plan]; the gas accumulated here, and the return air-course ran in this direction over the furnace. There was a place about here we called the stables, but it is not shown on this plan, but all along here were doors for the purpose of conducting the air along this portion of the colliery. Every one of these doors were blown out and destroyed, not a vestige remaining. The next outbreak took place at the other end of the mine, in this direction [pointing out the spot on the plan]. These explosions were before the introduction of the safety-lamp. I have not the least doubt that the adoption of the safety-lamp in this colliery has been the means of saving a great number of lives.

Mr. HANDEL COSSHAM—In order to work a colliery in this way, I apprehend that you keep doubling the face by working upon each side?

Mr. WOODHOUSE—No; the principle upon which we work is this. If the men are here [pointing to the plan], we double the face by working on the sides; but if there [pointing out the spot], they only work half one day and half another.

Mr. HANDEL COSSHAM—That really requires you to double the face, and you find the advantage in getting larger coal?

Mr. WOODHOUSE—Yes; the task of hewing is lessened.

Mr. HANDEL COSSHAM—Can you state the quantity of coal that each hewer would probably hew in a day?

Mr. WOODHOUSE—I should not like to make a statement of that kind in figures from memory, without being sure that I was entirely accurate. I could give it, but it would only be a guess, and I should prefer on such a point being entirely accurate.

Mr. HANDEL COSSHAM—Nor the cost of that machine, I presume?

Mr. WOODHOUSE — You are probably aware that this machine [pointing it out], in conjunction with other machinery, has been working for three or four years at Staveley. I have seen it many times, and its action is satisfactory; very much so indeed. I would strongly recommend the curious in such matters, who may be going into that neighbourhood, to go and see it, for I certainly think it is well worthy of attention; and now I am on that subject, I will add, that if any gentleman is disposed to make a journey to Shipley, in order to inspect this colliery, I shall be most happy to afford him every facility for doing so.

Mr. WYNNE—I do not imagine that it must necessarily follow that there will be an increase to any extent of loss of life by the adoption of the system of long wall working, for that has been proved by the adoption of the system in Shropshire, where there has not been many lives lost, and I am happy to say, that a very large quantity of coals has been obtained by that system of working. In North Staffordshire, where great attention is paid to the system of timbering, and where it is carried to great perfection, the loss of life is very limited indeed. I can quite bear out the statement which has been made by Mr. Woodhouse in the able paper with which he has favoured us, that the system of working collieries by means of long wall work has very much deteriorated, and, in many instances, men are put into a pit to work on that system when they do not understand it in the slightest degree. The natural consequence is, that accidents occur through negligence or want of knowledge and lives are lost. But if you work a colliery by the long wall system,

in which the men are perfectly up to their work, and in which the best system of timbering is adopted, I do not think there is any mode of getting coal that has been discovered to be safer than working by the long wall system. Even if you leave pillars, there would be more danger in getting these pillars where there is gob on each side than where you have the solid coal. As far as the system has been proved with respect to the Derbyshire coal-field it bears comparison (with respect to its results) with that of Shropshire; and it certainly shows that there is not the slightest ground for any apprehension that there would be any increase in the loss of life, even in the event of the general adoption of the system of working by the long wall system. But the system of working in North Staffordshire I consider still better than that which has been adopted either in Derbyshire or in Shropshire. I do not wish to be misunderstood; I am not speaking of South Staffordshire, where they do not go to the far end and then bring the coals all the way back. However, that must be governed by the character of the different strata through which you pass. Where you go to the far end, the boundary of the colliery, and bring the coal back it is safer, I think, but as I said before, that is a matter in which you must be guided by circumstances.

Mr. Woodhouse—As the member who has just addressed the meeting has alluded to the system, which is sometimes adopted, of driving out to the far end of the mine, and bringing the coals back, thereby obviating the necessity of packing and preserving the goaf roads, I would recommend to his particular attention the consideration of the system which has been adopted in the coal mines in Warwickshire, and which, I may add, is almost universally adopted in that county. I believe that there are present in this room several very eminent mining engineers from that district, who, I dare say, would be very happy to give him any explanation he might require upon that point.

Mr. Reid—Have you applied the underground engine for the purpose of haulage in this particular colliery?

Mr. Woodhouse—Yes; I think there will be a paper read upon this subject as soon as this discussion is done. I believe that that is the next paper which is to be read. If you go into Derbyshire and see those works at Shipley, you will be invited to Cinderhill; and I commend to your particular attention the colliery of the Butterley Company, in which there is a very extensive long wall working, which is done right well, and I have not the slightest doubt that the intelligent engineer of the Butterley Company will do everything in his power to facilitate your examination of it.

The PRESIDENT—I have no doubt, gentlemen, that after the observations which you have heard from Mr. Wynne, followed by those of Mr. Woodhouse, you will have come to the same conclusion that I have done, namely, that inasmuch as we have not yet had a paper either upon the North Staffordshire or the Warwickshire Coal-fields, it is to be earnestly desired that these two gentlemen will be so good as to furnish us with some account, in detail, of the practical mode of working these two districts. Whilst I am speaking, I may, perhaps, be permitted to make one observation with reference to the principle of working coal by long wall, which is that of availing ourselves of the pressure of the superincumbent strata, for the purpose of separating or detaching the coal which is in course of working from the bulk, and then to allow the superincumbent strata to fall or settle down on the goaf, and so to become solid by means of such subsidence and by packing. The principle of safety is, of course, involved in the goaf becoming comparatively solid next to the face of the working, or where the coal has been separated from the solid coal, which, as Mr. Woodhouse says, is not the case where the pillar and stall system of working the mine is adopted. I do not wish to go into the comparative merits of the two systems, one of which is so generally adopted in the one district, and the other in another. Apart from the comparative merits of the respective systems, there is much in the nature of the coal itself, and in the strata with which it is associated, to render it advisable to adopt the one system or the other. But, in adopting the system of pillar and stall working, I may be permitted to state, that the principle of pursuing such system is always to leave pillars of such a magnitude and strength that, in whatever stage of working they may be, there should constantly be sufficient strength of pillar to sustain the superincumbent strata without crushing the coal, and so to secure large coal. Formerly, I am quite willing to admit, the system of working by pillar and stall was, to leave only as pillars just so much of the coal as was capable of supporting the roof. So long as the pillars remained perfect, things went on properly and right enough, but when you began to take away the pillars, or to weaken them by taking away a portion of them, a creep or thrust was produced, then the crash came, and it was very often attended with great danger, and sacrifice of coal and sometimes of life. Having had great experience in the pillar and stall mode of working, I can state that the principle which is now in operation in working mines by that system, by leaving the pillars of such a size that they are amply sufficient, in every stage of the process, in getting the whole of the coal, to support the superincumbent weight.

Such a mode is very successful, both in obtaining all the coal, and also in obtaining it in the best possible merchantable state. Pillars must always, however, be left of adequate and ample strength, and the working so conducted, that whatever may be the quantity of coal taken away from each pillar, the quantity and position of the remaining coal should be amply sufficient to support the superincumbent weight of the strata without crushing such remaining coal, and not to allow the incumbent strata to be broken down prematurely. In point of fact, where that method is effectually carried out, the principle of working a mine by the system of pillar and stall, is very similar to the system of working by long wall, viz., in both cases to have always a sufficient strength of pillar, or of solid coal next the face, to support the superincumbent strata, without its being crushed by inadequate strength; and the system to which I have been referring, of working the pillar and stall method, is now, I believe, becoming pretty universal throughout the trade, where such system is practised. You will see some important papers upon this mode of working in the "Transactions" of the Institute.

Mr. BASSETT—Before we proceed with the next paper, I beg to propose a vote of thanks to Mr. Woodhouse, for the very able paper with which he has favoured us, and in doing so I cannot but express my own feeling, which, I believe, is the feeling of the meeting also, that at all events South Staffordshire men owe a great debt of gratitude to Mr. Woodhouse for the light he has thrown upon the question.

The vote having been cordially agreed to,

Mr. WOODHOUSE said—I thank you heartily for your kind notice of the paper, and I can only say, that if I have said anything which is at all interesting, or which tends in the slightest degree to the improvement of mining, any trouble that I may have been put to is far more than repaid by your approbation and encouragement.

The PRESIDENT then called upon Mr. Stuart Smith to read a paper.

ON THE

WINNING AND WORKING

OF

CINDERHILL COLLIERY, NEAR NOTTINGHAM.

By C. F. STUART SMITH, Derby.

The meeting of the members of an Institute exclusively devoted to mining and its collateral branches, in the Midland Capital of the Coal and Iron Trades, appearing a no ordinary opportunity for bringing under notice the state of development which coal mining has attained in the Midland district, the writer trusts that the following sketch of the winning and working of the top hard seam at the Cinderhill and Babbington Collieries may not prove uninteresting.

The intention is to give a succinct account of this undertaking from its earliest commencement; pointing out, in proceeding, the various stages in the development of its resources, and such peculiarities, both physical and scientific, as may be deemed worth notice.

The works comprised in the Cinderhill and Babbington Collieries will be briefly glanced at; then their physical and geological position, especially that of Cinderhill; thirdly, the system there adopted, and the extent of the works at various stages in their development; and, lastly, the economy of the works from the commencement to the present time.

The Babbington and Cinderhill Collieries are now the property of Thomas North, Esq., and consist of five distinct winnings, three of which are in full working operation, and the other two will also be before the ensuing winter.

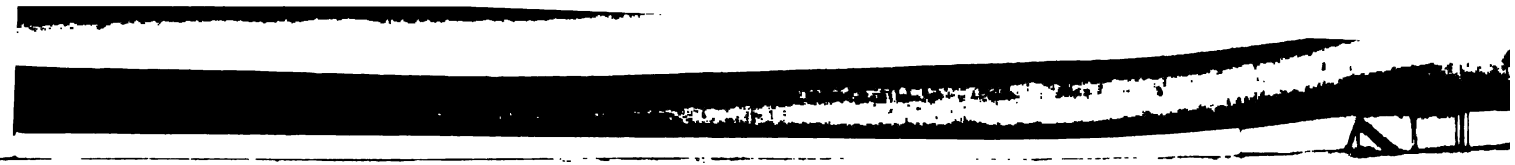
The seams worked are, taking Cinderhill as the point of section, the top hard, 222 yards deep, 5 feet 2 inches thick, used for house and steam purposes; the deep soft, 382 yards deep, 3 feet 1 inch thick, a bright, swift burning house coal; and the deep hard, 398 yards, 3 feet 3 inches thick, a strong steam coal.

The collieries are named, first, the Cinderhill No. 4, or Nuthall Pit, (*vide* map II.), 222 yards deep, working the top hard seam, an account of which will form the chief subject of this paper; secondly, the Newcastle Pits, 136 yards deep, also working the top hard seam; thirdly, the top hard at Kimberley, 125 yards deep, the headings for working which are now being driven; fourthly, the Babbington No. 2, or Kimberley Pit, 273 yards deep, working the deep hard and deep soft seams; and, fifthly, the Cinderhill, Nos. 1 and 2, or deep pits, 480 yards, where the workings in the deep soft seam are in the course of being opened. In addition to these, another winning, to be called the Broxtow Colliery, and which is to work the deep hard and soft seams, is already sunk to some depth, and arrangements are made for setting on almost directly other foundations. There are also large ironstone mines at Babbington, belonging to Mr. North, but worked by the Stanton Iron Company.

The whole of these works are in the south-west corner of Nottinghamshire, and are situated in the immediate vicinity of the town of Nottingham, the Newcastle Pits being within two miles, the Cinderhill within three miles, and the Kimberley, or Babbington, within five miles of that town.

The present outlets for the disposal of the coal are (*vide* map II.), on the east, by the Nottingham and Mansfield Branch of the Midland Railway, which brings these collieries nearest of any in Nottinghamshire or Derbyshire to the Great Northern Railway system, *via* Grantham, for the shipping ports of Grimsby and Boston, and also for the home trade in that district. The Nottingham Canal, which is in connexion with the Trent Navigation, also forms an outlet on this side; and on the west the communication is by the Erewash Valley Branch of the Midland Railway, connecting the collieries with the Eastern Counties and London and North-Western Railway systems, and also by the Erewash Canal, which is tributary to the Grand Junction and other Canals. The principal vend is, however, by landsale for the supply of the town and neighbourhood of Nottingham, both with house and steam coal, which, in addition to being sold at the various pit mouths, is, for the convenience of the traders, conveyed by private railway to six different wharfs, situated at the most convenient outlets (*vide* map II.), over a district eight miles in extent, reaching from the Radford Wharf, within one mile of the very centre of Nottingham, to Ilkeston, in Derbyshire. The railways are worked by locomotive and stationary engine power.

The whole of these collieries which are now being worked are situated (*vide* map II.) on the magnesian limestone and lower new red sandstone,



MECHANICS' INSTITUTE
SAN

or Permian formation; and Cinderhill, the most eastwardly of them, was the one first sunk. Its geological position will be more clearly understood by reference to map II., where will be seen, on the right hand side, coloured various shades of red, a tract of light red sandstones and drift gravel, stretching east and spreading over a wide district, the boulders in which are supposed to have been washed from the granitic rocks of Norway and deposited here. Next to this lies the magnesian limestone (*vide* map II.), coloured buff, extending over a considerable area, and resting on the lower new red sandstone, coloured purple, a narrow belt of which, of nearly an uniform width, is seen cropping out along the greater portion of its western margin, and lying immediately upon the coal measures, coloured grey, which extend thence several miles to the west.

Whether the lower new red and magnesian limestone lie conformably to the coal measures is very doubtful. In fact, it is generally supposed that they do not. The coal measures mostly have an uniform dip towards the east.

On the south and south-east side (*vide* map II.) a large fault abruptly terminates the coal-field against the new red measures, while to the north it stretches uninterruptedly beyond Leeds. It was then, on the east side of this coal-field, and within four miles of its southern extremity, and within three miles of where the red ground had been worked up to on the south-east, but considerably in the dip of all workings in the neighbourhood, that, in 1840, the then proprietors of the Babbington old collieries determined to try and win the top hard seam.

The magnesian limestone had not at this time been sunk through in this district, or such a thin crust had been met with as not to have been noticed, and there was an opinion prevalent that the coal measures terminated abruptly against the new red formation on the east, as on the south and south-east (*vide* map II.).

Some forty years previous the estate had been reported on by the most eminent viewer in the district, and pronounced to contain no coal, and this was still the general belief, so much so, that only a few years previously a large portion of the adjoining estate had been sold for a comparatively small amount. The proprietors, however, commenced to make trials, by sinking and boring; but the variable thickness, and apparently contorted position of the magnesian limestone confirmed, in the minds of most people, the belief that the coal in this district was cut off or thrown out.

In the meantime Mr. North was unwilling to abandon the establishment of a colliery in so favourable a situation without another effort.

For a considerable time previous to this Mr. Woodhouse had been fully persuaded that the eastwardly dip of the coal measures continued uninterruptedly under the magnesian limestone, and in order to prove the correctness of this, which was a favourite theory of his, he had, in 1839, at considerable cost, undertaken a deep boring on the Duke of Newcastle's estate, at Lady Lee, near Worksop, (*vide* map II.,) and close to the present Shire Oaks Colliery, about twenty-two miles north of Cinderhill, where, after passing through about 160 yards of magnesian limestone, and lower new red sandstone, the coal measures were found, as he had anticipated.

In 1841 a pair of seven feet shafts, the present Nos. 1 and 2 pits, were commenced at Cinderhill, near to the trial holes, and after sinking through about sixteen yards of magnesian limestone and red sandstone, the coal measures were reached; and, at the depth of 222 yards, the top hard seam, five feet two inches thick, was won.

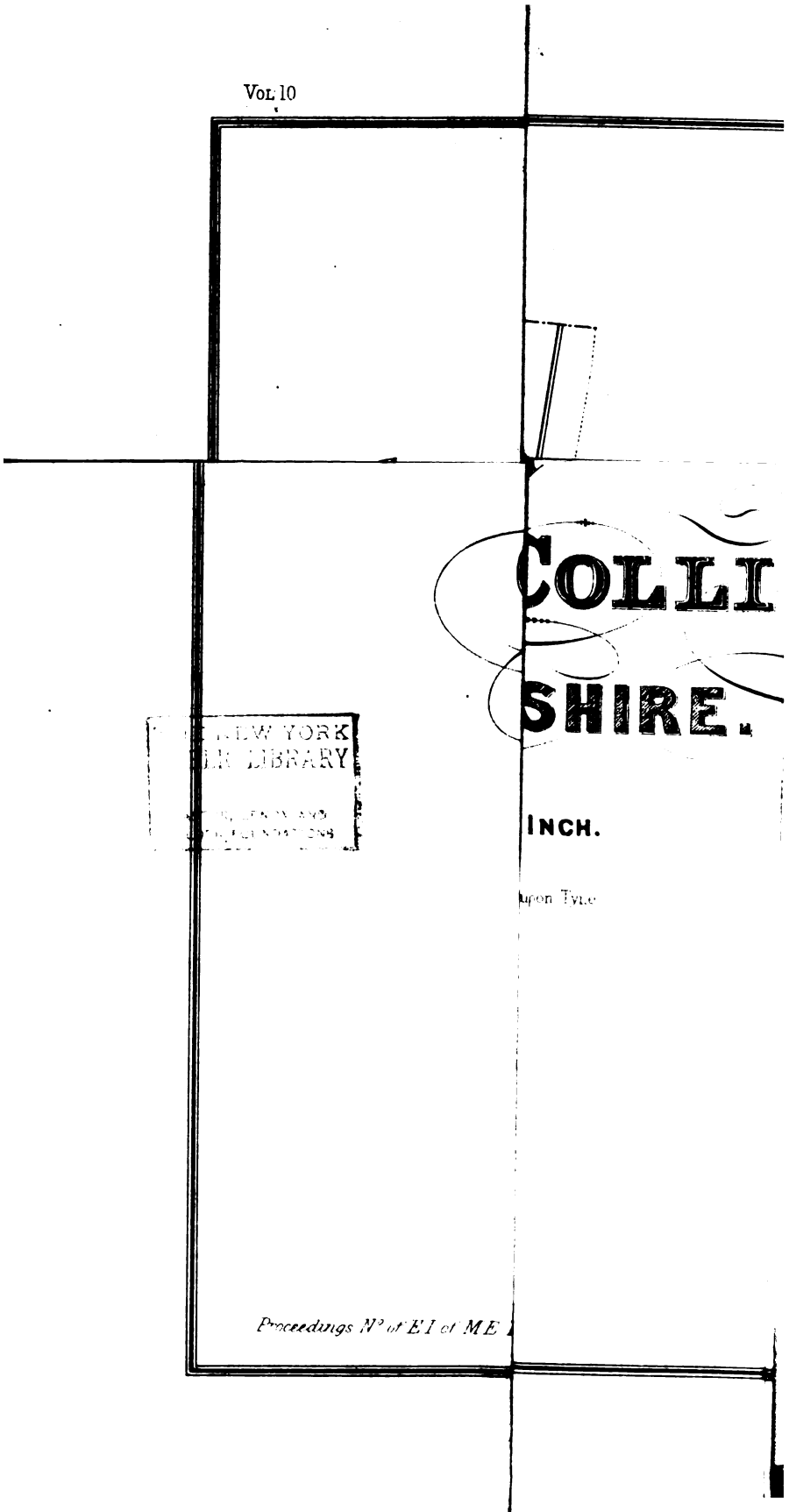
In laying out the works, it was determined to adopt a system which would ensure their full development on a scale commensurate with the important position it was foreseen they were destined shortly to occupy.

After the opening of the colliery the demand rapidly increased, and as rapidly were the works extended. On the north side, which was the district first opened, a large fault was ascertained to run north-west and south-east, at some distance in advance of the faces; and another upthrow having been met with in the levels, running in a more eastwardly and westwardly direction, it became necessary, in order that the supply might not fail, immediately to make preparations for opening new works on the estate, the greater portion of which lay on the north-east or dip side of the levels, and was unproved.

A stone drift was driven from the No. 1 pit bottom to the fault in the deep, and levels driven to the south; but this district proved to be so broken up by faults as to preclude any great extension of the works in that direction.

There was still a very general opinion that the fault to the deep was the boundary of the coal-field, or its eastward termination against the new red formation.

Various obstacles combined to render the opening of another and distinct winning on the estate impossible. There was the landlord's objection to having his property cut up by railways and cart roads, and to having the works brought into any closer proximity to his mansion. There was



NEW YORK
LIC LIBRARY

the consideration of the expense of sinking a deep foundation on unproved ground, and of constructing the works for the conveyance of the minerals, if found. But, above all, there was the necessity, in order to avoid competition, of keeping near the market; for though by this time (1845) a new line had been constructed to the Nottingham Canal, and a wharf made for water-sale within three miles of the colliery, and the Erewash Valley Railway, about four miles distant, was in progress, which now form main outlets, still the legitimate vend was undoubtedly by landsale, and any new winning must have been made at a greater distance from Nottingham. It was, therefore, determined not to remove the establishment, but to drive through the fault on the deep side of the north levels, and so prove the estate. Accordingly, in March, 1845, a stone drift, running N.E. 16°, was commenced at the end of the north levels. For two years this was unceasingly driven on. It was carried six feet wide, with a brick brattice down one side for ventilation, and at the expiration of that time it was nearly 700 yards in from where it struck off from the levels, and still the signs of finding the coal were as dubious as ever. The dip of the measures was considerably less than on the west side of the fault, not being above one in eight, and the level course was altered 40° to the north, and it began to be confidently asserted that the coal would not be found. A mining engineer of the district went down and examined the drift, and reported to the proprietors that it was useless to prosecute the work farther, for there was no coal to be found. In three days after this, while the proprietors were yet undecided whether to take this gentleman's advice, and abandon the search, the coal was found on the 14th of September, 1847, at 730 yards in from the level, of full thickness and equal quality to that on the south-west side of the fault, thus corroborating the theory of the continuous eastwardly dip of the coal measures under the magnesian limestone. The drift was now stopped, and preparations were made for sinking a shaft at the extremity of it, for the purpose of ventilation only.

This new upcast, or No. 3 pit, was made ten feet in diameter, and tubbed and lined with fire-brick. It is a little to the rise of the stone drift (*vide* map I.). As soon as the shaft was down, the stone drift was arched nearly throughout its entire length, except where the measures were sufficiently strong to stand without support, the road being made from five to six yards wide, and laid with a double line of chair rails, 30 lbs. per yard.

At this time Mr. North, who was now sole proprietor, was very anxious

to prove the deep seams on this estate without delay, as the demand for these descriptions of coal was greatly increasing, and his supply was limited. It was, therefore, determined to sink the Nos. 1 and 2 shafts down to the bottom hard and soft seams, 180 yards lower, and also to sink another and larger shaft for drawing from the top hard, and also as a downcast.

On the 10th of August, 1853, the present winding shaft, called the No. 4 pit, was commenced over the north level, and but a short distance from the Nos. 1 and 2 pits. An interesting circumstance may here be mentioned, connected with the sinking down of the No. 2 pit to the bottom hard. This shaft was still being used for coal drawing, the No. 4 not being ready to take its place, and a difficulty arose how to sink this shaft down without interfering with the coal drawing. There was a stone drift twenty-five yards below the bottom of No. 2 pit, which is the one mentioned as being driven to bring the coals out of the south district. Of this, and the inclines connecting it with the shaft, a very careful survey was made, and then the drift was extended exactly under the No. 2 pit, and the centre of the shaft above accurately determined. A gin was erected in this stone head, and sinking commenced without causing any interruption to the coal drawing. Afterwards, the crust of twenty-five yards, between the original bottom of the shaft and the new one to the lower mines, was sunk through, and the centre proved to be perfectly true.

As the works in the No. 3 district progressed, a deep incline, or what is called Bulwell Plane (*vide* map I.), was commenced to be driven to the boundary, and is now 1000 yards to the deep from the top levels, from which point another set of levels strike out north and south, and works are being opened. In driving these north levels a singular swamp was met with in the coal which was found to dip on all sides, after the levels were a short distance from the incline, and which has, in its lowest part, a depth of above thirty yards perpendicular. Indications of this were observed in driving the plane, but nothing material. There is no perceptible thickening or thinning of the seam, but in the swamp a large quantity of water lies.

The workings in the north district were exhausted in 1854, after having been at work for eleven years; and the south district only lasted five years, from 1847 to 1852. There is now at work the No. 3 district, which, supposing the whole supply at the present rate had to be drawn from thence, would last about fifteen years longer, but which will

probably last double that time, as it is intended, when the Bulwell district is developed, and the supply can be obtained from it, to ease the gets from the top levels, so as to work about an equal proportion of deep coal.

It now remains to consider the last head, viz., the economy of the mine.

Commencing at the outset, in 1840, at the sinking of the new winning, we find the first of a series of practical and scientific improvements hitherto unknown in the Midland Counties, the adoption of which has worked a revolution in the coal mining of the district, and made Cinderhill rank among the first and best collieries in England. During the process of sinking considerable feeders of water were tapped, and it was immediately determined to use metal tubbing for stopping them back, and at fifteen yards from the surface the first metal wedging crib was laid. There are two more cribs in each shaft, the lowest being about ninety-four yards from the top. At this date, 1841, the only description of tubbing used in this locality was the wood tubbing; metal tubbing, though well known in the North of England, had not yet been introduced, and great was the prejudice against it, both of the proprietors and workmen, which had to be overcome. The proprietors having been accustomed to work shallow pits, involving but a small outlay, considered that even if the metal tubbing should be effectual, the first cost was excessive, and the workmen boldly pronounced it unsafe, said it could not be made water-tight, that it would be worn away shortly by oxidization, with numerous other objections. To combat all this required unceasing vigilance and energy; still the work progressed satisfactorily, and in little more than twelve months both shafts were down to the coal, and perfectly dry.

In 1842, when the coal was won, the Midland Railway Company was then in its infancy, and neither the Mansfield nor Erewash Valley branches were constructed; and as the canal wharfs belonging to the colliery company, both on the Erewash and Nottingham Canals, were between three and four miles distant, the colliery was intended chiefly as a landsale for the supply of Nottingham, and accordingly a thirty-horse horizontal engine, with flat hemp ropes for winding, was erected, it being considered that this would be able to draw sufficient coal to meet all demand. The shafts were fitted with wooden conductors, and cages on the most approved plan.

A pair of levels and a head for opening off the stalls were driven out north-west, and the workings commenced on the Derbyshire long wall

system (*vide* map I.), the whole of the coal being extracted, the faces working to the rise, and packed inclines through the goaf for the conveyance of the coal from each stall to the level, at about every forty or fifty yards, being carried forward as the workings progressed.

The rise of the mine was about one in five, giving an ample gradient for a series of self-acting planes, and thereby much simplying and reducing the cost of underground conveyance.

The mine proved to be perfectly dry, though fiery, a circumstance unusual in the district; and in consequence of the workmen being very incautious and unaccustomed to any amount of ventilation, great care was requisite in the management. The furnace arrangements were on a scale previously unknown in the district, and the quantity of air passed, though only about 25,000 cubic feet per minute, was considered by the miners excessive. After-experience proved it to be insufficient, and, as the works extended, the quantity had to be increased. The ventilation was exceedingly simple, owing to the method adopted in working the coal. The intake current, travelling along the main working levels, was split at the bottom of certain of the inclined planes, and conducted to the face, whence, after sweeping along an allotted length of the banks, it was conveyed to the upcast by a main return air-course. And this, in 1849, being found heavily charged with gas, a dumb drift, the first, I believe, ever made in the district, was driven. In the meantime, the demand had so much increased as to require a greater daily output than the engine was capable of drawing. To meet this, a more powerful winding machine, a thirty-inch high pressure vertical engine, with twenty feet flat rope rolls, was erected.

This machine was sufficiently powerful, drawing only a single corf at a time, averaging ten cwt., to raise to bank between five and six hundred tons of coal, exclusive of slack and dirt, per day, the whole of which was conveyed from the workings to the levels by self-acting inclines, and then along the levels to the pit bottom by horses.

When the No. 4 shaft was sunk on the north levels, it was made both the downcast for the works, and conducted and bratticed for winding double. A forty-inch high pressure vertical engine, with eight boilers, was erected, for winding with three-tier cages.

The No. 3 district, with which the stone drift communicated, was also opened on the long wall system, as had in the first instance been adopted, and ventilated in a similar manner, the furnace being nine feet wide by nine feet long, in a twelve feet arch. At first, owing to a difficulty in

getting the No. 3 pit to upcast, a Biram's fan was placed at the top of the shaft in order to ventilate the works, and was worked by the small engine which had been used in sinking, but this was abandoned as soon as the furnace could be got to act. The quantity of air now passing is about 60,000 cubic feet per minute. The mine in this district is found to give off very little carburetted hydrogen.

By referring to the plan No. I., it will be found that from the shaft to the point where the stone drift intersects the coal the distance is 1180 yards, and the nearest working place, in the first instance, would be at least 240 yards more, or 1420 yards from the shaft; and to the boundary, where the works would ultimately have to be pushed, it is on the level course 3500 yards from the pit eye. The royalty also extended 2800 yards to the deep of the levels. From this it will be readily understood that the most economical and effective mode of underground transit was a most serious and important consideration.

To convey the coal by horses for such distances was not to be thought of, and steam power was the only one applicable. A twenty-inch horizontal engine was placed near the bottom of the No. 3 or upcast shaft, with three boilers, and gearing for working an endless rope. This is a wire rope, 1¼ inches in diameter, and is run on rollers placed five yards apart, and at the bends in the level it is kept in its position in the centre of the roads by binding sheaves, and at each extremity passes round a turn-wheel, seven feet in diameter. Great care has been used to reduce friction to the lowest possible point, and to take advantage of every appliance for reducing the cost of conveyance as much as possible. At first, this rope only came from the drawing shaft to the engine, 1180 yards. It was afterwards carried 250 yards farther, and lately it has been taken 210 yards farther still, and it is intended to extend it to the extremity of the present working levels before the ensuing winter, when it will be upwards of 5200 yards long, and will convey the coals 2580 yards, or 1½ miles nearly. It is kept in continual motion by the engine, which works with 15 lbs. of steam per square inch, and conveys at one time four trains, each consisting of thirty-two loaded trams, and four trains of empties, and these are at pleasure detached or attached while the rope is in motion, by means of tongs, a single pair of which grip the rope sufficiently tight to haul a load equal to about twenty tons. The tongs have a long leverage, and the hand is all that is required to make them grip. In addition to the main plane, the engine works the deep incline or Bulwell plane, and also a pump, which was required for raising

the water met with in the swamp, to the top levels, from whence it flows to the winding shaft, and is drawn at night by the engine. The total fall of the Bulwell incline to the present levels is seventy-three yards, and this is accordingly the height of the column of water which has to be raised. Six-inch trees were laid down the return air-course, with two sets of double clacks, and escape valves. An eight-inch plunger, with a stroke which can be regulated from two to three feet, worked by a quadrant, was fixed in a sump at the bottom of the plane, and the head of the plunger was weighted so as to just overcome the resistance of the column of water. Every part is most carefully adjusted and kept in order, so that at no part of the pump, even when in full stroke, is the slightest sound audible, and this is found to enable the engine to work the pump alone with only 3 lbs. of steam per square inch, when pumping eight strokes per minute. To work this plunger, wooden rods, four inches square, running on metal pullies two feet in diameter, were carried down the Bulwell plane, and connected with the engine by four to one gearing and a bell crank. The only "fend-off bob" required was at the turn in the level, the incline being perfectly straight. These, then, are the duties at the present time of the engine:—to work the main plane, 1640 yards long; the Bulwell incline, 1000 yards; and pump a six-inch column of water seventy-three yards in vertical height, at 1000 yards distance. The quantity of water raised by this pump daily (about eight hours being occupied in pumping) is 10,000 gallons, at a cost of 2·95 pence for every 100,000 gallons raised one foot high. The cost per ton for conveyance up the Bulwell drift is 1·44 pence, or at the rate of 2·53 pence per ton per mile; and here it must be mentioned, that this incline is unfinished, having at present only a single rope on it, and the quantity of coal brought up being small, owing to the works not yet being in full operation. On the main plane the cost per ton is 1·20 pence, or at the rate of 1·28 pence per ton per mile, and on the horse levels and self-acting planes at the rate of 6·55 per ton per mile, making the average cost of underground transit 3·45 pence per ton per mile.*

The expense and inefficiency of oil lamps and candles for lighting so great a length as 2000 yards of road, along which the main intake current was passing, led to the introduction of gas underground. Works were established in 1858 on the surface, and a three-inch main passed down the downcast and along the plane to the engine, and a two-inch

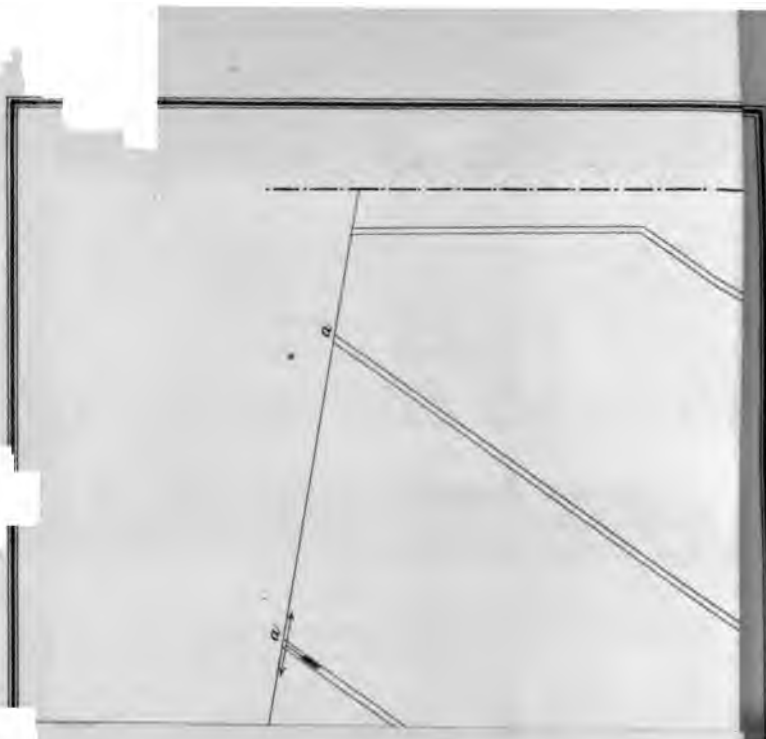
* All wages, stores, and repairs are included in these calculations, but not interest of capital.

main continued forward some distance. From these, service pipes were taken, and lights placed every twenty yards along the plane and levels. The gas is made to descend the pit by a fall of water through the vertical mains, causing an exhaustion of gas from the holder, which being driven on by the weight of falling water above it, is compressed in the horizontal mains in the pit. There are now upwards of one hundred lights used in the pit. In order still farther to economise labour, blacksmiths' and carpenters' shops, together with a store room and office, have been built near the underground engine, which, together with the stables, are lighted with gas. There are only seventeen head of cattle in the pit, viz., five horses, ten ponies, and two donkeys. The works have all been laid out on an extensive scale, with the view of raising a large quantity at as small a cost as possible; but hitherto not more than 600 tons per day have been drawn, and this is entirely owing to a system of limitation on the part of the miners, who have been, till lately, under the influence of an union which has been subversive of all discipline, and detrimental alike to the employer and employed. The depression in trade has, within the last month or two, done much to break up this baneful agency.

Since the first opening of this colliery, there have been twelve fatal accidents, and 1,448,132 tons of coal raised, or one life lost for every 120,677 tons got.

The other collieries at Babbington, Cinderhill, and Newcastle are carried out in a similar manner to the one here described, though they are not at present so extensive.

The PRESIDENT—I beg to move a vote of thanks to Mr. Smith, for the interesting description he has read to us of the working of this colliery. Carried by acclamation.



NEW YORK
BLIC LIBRARY

ON THE METHOD ADOPTED IN

WORKING THE MAIN SEAM OF COAL

AT

MOIRA, IN LEICESTERSHIRE,

PARTICULARLY WITH REFERENCE TO SPONTANEOUS COMBUSTION.

By GEORGE FOWLER, Ashby-de-la-Zouch.

About twelve miles south-west of Derby there occurs an isolated patch of coal measures which, from its resemblance in some points to both the Derbyshire and Warwickshire coal-fields, claims to be an outlier of each, and from its position, occurring nearly midway between them, affords a plausible reason for the theory that it has at some period connected them. It is not necessary, nor indeed possible, to give any detailed description of the structure of this coal-field, the subject of this paper being the working of a seam found in one portion only of the district; but the following outline will, it is hoped, be found interesting.

The extreme length is about twelve miles, extending from Burton on the north-west to Coalville on the south-east, and its breadth nearly eight miles. It is bounded on the north-east by a large upthrow fault, calculated by Mr. Hull to be, at the south-east end, more than 700 yards vertical, but diminishing considerably farther northward. On the south-west its boundary is not clearly marked; there are numerous faults running north-west and south-east, some concealed by the overlapping sandstones, others breaking through them, and, consequently, of later date, and whether by one of these faults the coal is thrown out or not it is at present hard to say. On the east, syenitic rocks, surrounded by Cambrian slates, appear above the surface, tilting up the coal measures at a steep angle. It is considered probable by geologists, that though these igneous rocks have been greatly elevated since the deposition of the coal measures, still that they were in existence before, and formed a shore round which these strata were deposited.

On the north-west the coal measures crop out beneath the new red sandstone. Through the middle of the field, from north-west to south-east, runs a strip of unexplored, and, it is believed, barren coal measures, about two miles in width, which divides it into two portions extremely unlike one another in the sectional arrangement, in the quality of the coals, and in their number and thickness. It is true that many attempts have been made to compare them together, but the success has been so little, commensurate with the labour bestowed, and the conclusions arrived at so different, that they may be rejected as unsatisfactory. Mr. Hull submits a theory that both portions are of the same age and on the same geological horizon, but that their individual beds have no connection. It may be also noticed that the Coleorton district somewhat resembles the Derbyshire coal-field, while in several particulars the Moira basin is much like the Warwickshire and South Staffordshire coal-fields.

In one particular this general similarity is striking; the Moira main coal and some of the Staffordshire and Warwickshire beds are alike subject to spontaneous combustion. Now, till the causes which produce this liability are fully understood, and the reasons why it is confined to certain seams in one or two coal-fields are known, it would be arguing on very imperfect data to consider this peculiarity in a seam in one district any proof that it was equivalent to a bed manifesting the same tendency in another, especially if no other reason could be advanced. Still, the facts are in themselves peculiar, and their investigation may throw light not only on the connection between different coal-fields, but on the yet unsettled question of the origin of coal itself.

The general dip of the Coleorton portion is south-east, extending regularly from the millstone grit to the sudden termination of the coal measures by the syenite. In the north-west portion of the Moira district the dip is also south-east, but about midway it changes, and in 1½ miles by a natural rise of one in ten, and by a series of upthrow faults, more than 1000 feet of coal measures crop out at the surface. It may be noticed as a singular fact, that in the Coleorton part there is scarcely a fault, and that the measures actually dip towards the syenite; whilst in the Moira district, remote from igneous rocks, the strata are so broken up by faults (many of them large), that in one of the earliest collieries sunk it would have been hard to have gone fifty yards without meeting with one.

The method of work which experience has proved to answer best is the long wall of the Midland Counties, modified to suit the nature of the coal.

As from the irregularity of the faults, the plan in which it is applied differs at every colliery in form, though in principle the same, perhaps it would be better to treat of one colliery only, of which the diagram is a sketch, which, though inaccurate as a plan, from the impossibility of showing the extent of the workings to a scale sufficiently large to give the details of each, shows clearly the method of working. The coal at this colliery (the Newfield) is from twelve to fifteen feet in thickness, but of this, owing to inferiority of quality and difficulties of working, only six feet are at present worked. The section is—

Clunch and batt.....roof.
Over coal .....2 feet....very inferior, left.
Main coal .....6 „ ....good, got.
Nether coal .....6 „ ....variable, left.

It may, perhaps, be a matter of surprise why, from so large a thickness, comparatively little is worked. The two feet of over coal left is far too inferior to pay the cost of extraction, and the nether coal is so far bad, that it is doubtful whether it would compensate for the increased cost and danger in extraction.

The Moira coal is especially a house fire coal, but the nether coal does not come up to the standard which this purpose requires. When, from the exhaustion of other seams, coal is getting scarce, it will then doubtless be reworked.

The whole thickness is composed of frequent alternations of dice and spire, which makes it tough to get down when holed, though tender and dusty when got. Perhaps the crushing caused by the many faults has also tendered it. Above the coal lies a soft batt and clunch, and beneath it clunch and hard rock.

It will be seen on the diagram that there are a series of large parallel faults running nearly in the strike of the coal; between these the coal rises generally about one in ten.

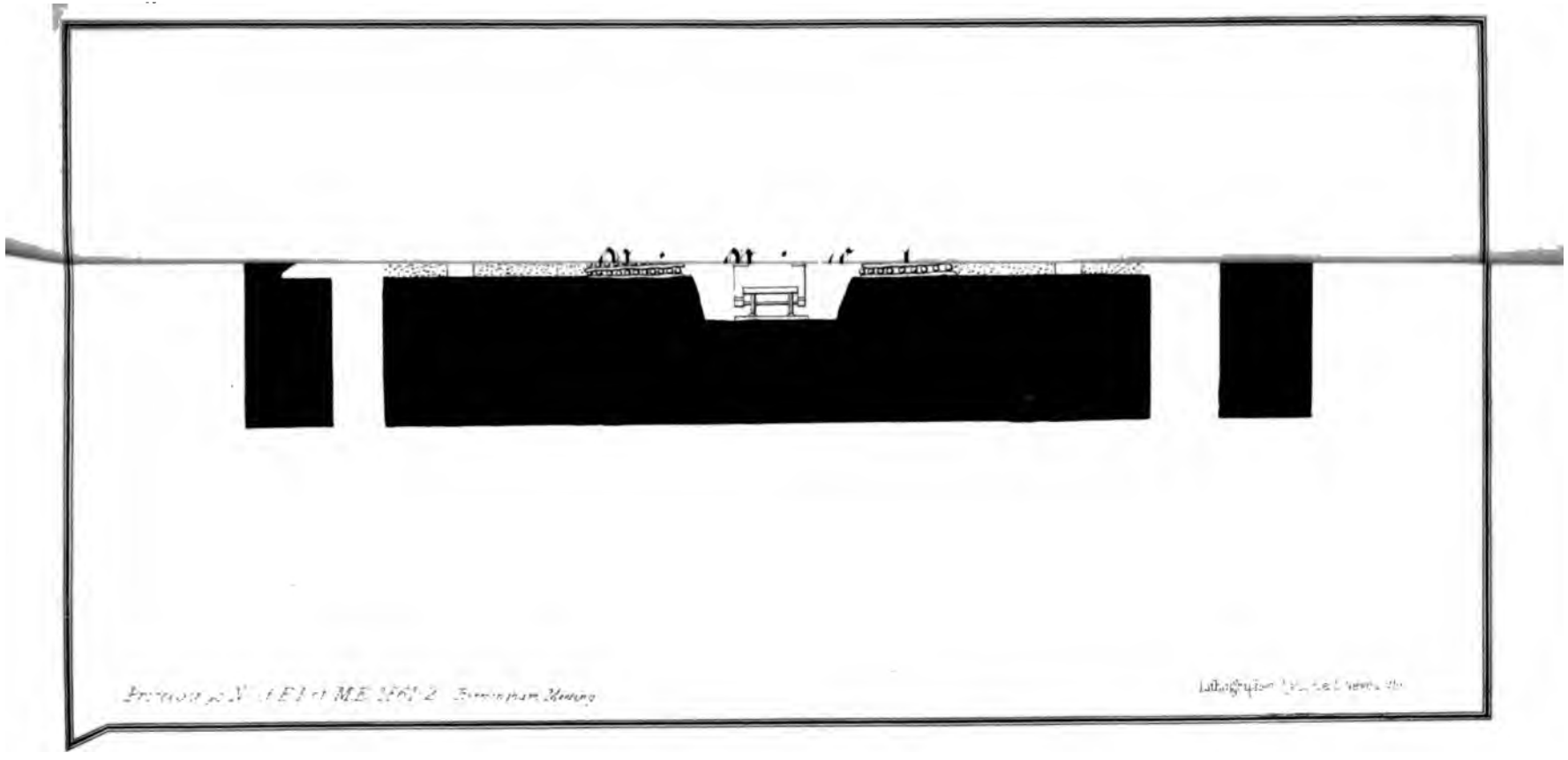
The faces extend in one straight line from fault to fault, and are divided into stalls of about eighty yards in length. One gate road is carried within thirty yards of the lower fault, and kept as nearly as possible on the level, and from it slanting gates are branched leading to each stall. In getting the coal it is first holed a yard under, and then brought down or driven by hammers and wedges; many attempts have been made to use powder in doing this, but from the tenderness of the coal, and the absence of any parting at the roof, they have hitherto failed. The roof is supported by three rows of iron or wooden props or puncheons, the last

row being knocked out and brought to the front, each time the face is holed. Though pretty good when well timbered, no great breadth of roof will stand without support.

The ventilation is very simple, the air current flowing from the downcast shaft to the centre gate end, where, splitting, it courses down the face and returns to the upcast shaft. The windheads are driven in the nether coal under the works, and communicate with the face by a roughly packed airway or carving, in which, at intervals of from ten to twenty yards, curry or staple pits are sunk to the nether coal head; by this plan the communication between the airways and the old wastes is easily closed.

From the absence of any stone or other material sufficiently hard above the coal, the gate roads are packed on both sides with short lengths of cordwood, laid in tiers lengthwise and crosswise, small slack being filled in to make it solid. To gain height, two feet of the nether coal is cut up under foot, and one or two feet of the top coal taken down. Inside the waste, and about four feet from the pack or brattice, a wall of stiff, well-tempered clay, locally called "wax," is built; and as this is done near the face when the workings are their full height, the sinking of the roof squeezes it out, and effectually seals up every crevice. The reason of this precaution is, that a current of air passing over any rubbish sets it on fire, and this liability to spontaneous combustion is the great difficulty found in working this coal seam. So inflammable is this coal, when acted on by a current of air, that pass-byes where waggons stand, or any place where there is an obstruction driving the current of air against the packs, is liable to fire. If a small crack in the over coal extends over the clay wall into the waste beyond, it will, if there is anything to cause a draught, fire. It is for this reason that the clay wall is built some distance from the pack, to lessen the chance of a crack extending so far. It is generally thought that the mixture of clunch with the slack increases the danger, but its presence is by no means necessary. Many curious instances of spontaneous combustion have been observed. The following may perhaps be interesting. At the place where a gate road branched, the smell of fire was perceived, but though the wastes on all sides were opened, no traces could be found. At last, by cutting down under foot, fire was found in the solid nether coal. A crack happened to run in the nether coal underneath the V shaped packing, and a draught of air drawing through it set the coal on fire.

It is curious, in looking over old plans of the collieries, to see the trouble that these fires have occasioned, and the precautions which have



PUBLIC LIBRARY
ASTOR, LENOX AND
TILDEN FOUNDATIONS

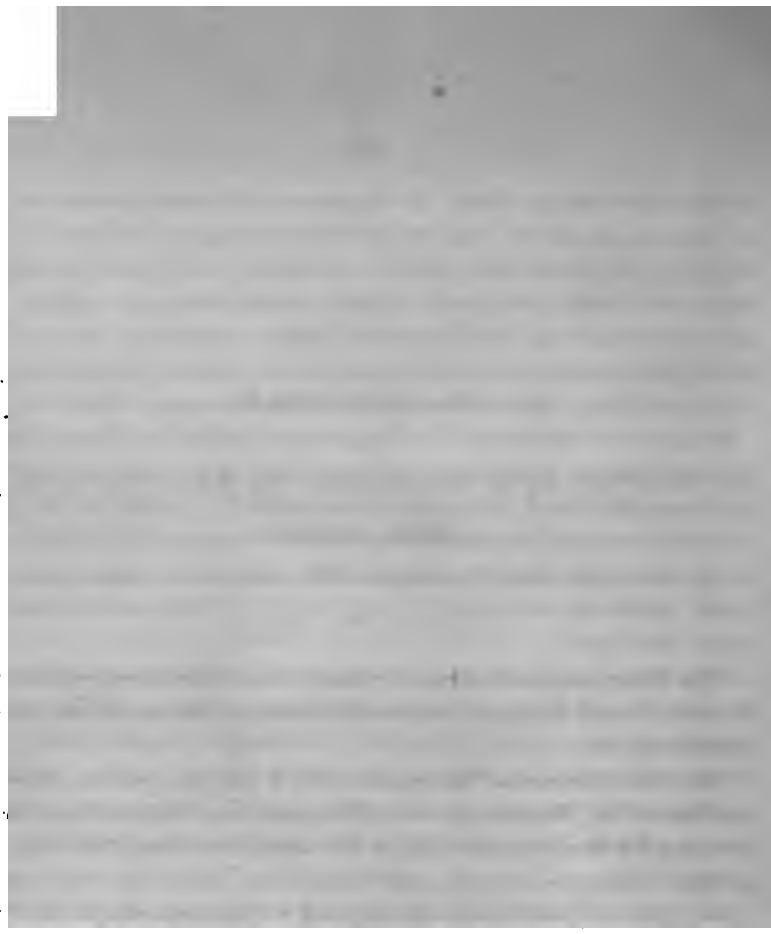
been taken to prevent them. In the earliest workings it was the custom to leave a pillar of solid coal on the side of the gate road; but this was not found to answer well. From the tenderness of the coal, the pillars, unless very wide, were much crushed, and the roads, both on floor and roof, were far more troublesome to keep in repair than when packed through the wastes; added to which, the cost of driving these roads, and the waste of coal caused by leaving the pillars, was considerable.

Trials were once made of pillar and stall work, but, as might be expected, the air could not be excluded from the wastes, and the tender roof coal and clunch falling down, increased the liability to fire. The plan now adopted has hitherto been found to answer best; fires rarely occur, and when they do, there is little difficulty in taking down the packs, removing the heating rubbish, and filling the place with sand or burnt spoil bank.

It is not so easy as might be wished to offer a satisfactory explanation for the causes of this liability to spontaneous combustion, for though the presence of iron pyrites is generally considered to be the reason, they often occur without showing any such tendency.

Perhaps the presence of salt, which, from its efflorescent qualities, moistens the coal and assists in the decomposition of the pyrites, may be a reason.

A careful analysis of the coal compared with others, and an accurate examination of the gases produced in the different stages of spontaneous combustion, would throw much light on the subject.



DISCUSSION

ON

MR. FOWLER'S PAPER ON WORKING THE MAIN COAL SEAM AT MOIRA COLLIERY,

PARTICULARLY WITH REFERENCE TO SPONTANEOUS COMBUSTION.

The PRESIDENT said—Having heard the excellent paper read by Mr. Fowler, I shall be happy to hear the opinions of the gentlemen present on the subject.

Mr. DARLINGTON—The reason why I put the question after the reading of Mr. Woodhouse's valuable paper was, that we have found very great difficulty in the Midland Counties in working the long wall system, arising from spontaneous combustion, which invariably occurs when the long wall spaces are exposed to the atmospheric air. The paper which has just been read is a very valuable one, and the diagram of the colliery exhibited very clearly shows the precautions which have been adopted at Moira to guard against spontaneous combustion. It must be evident to every one who has suffered from this very troublesome thing in mines, that it is a very simple and effectual way of dealing with it.

Mr. BLACKWELL—I think the mode adopted at the Moira Colliery, for the purpose of preventing the spontaneous combustion of coal, is evidently in principle the same as that which we are compelled to adopt in this district, namely, to exclude the atmospheric air. We have in this district a description of coal which is peculiarly liable, like the Moira coal, to spontaneous combustion, and the only way in which to prevent that spontaneous combustion, seems to be to exclude every particle of air from those places in which experience has shown that it is likely to occur. There is one very important consideration connected with this question of spontaneous combustion, and it is a point which deserves as much as anything can deserve, the attention of such an Institute as this, with a

view to its elucidation. The question which I wish to submit to you is this. What is the reason why certain descriptions of coal, situate in certain districts, have been proved by experience in working to be so much more liable to spontaneous combustion, than are certain other descriptions of coal situate in other districts? I do not think that that subject has been hitherto very carefully considered. It has, I believe, been generally supposed that the spontaneous combustion of coal arises from the action of the atmospheric air upon pyrites in the mine, which decomposes it. Gentlemen present will correct me if I have not stated in general terms, and pretty accurately, what is the almost universally received opinion with reference to the cause of spontaneous combustion in coal mines. For my own part, I have long entertained the opinion that it does not arise from the decomposition of pyrites. Spontaneous combustion takes place, as has been repeatedly proved, in coals which are quite free from pyrites; not only that, but it takes place most especially in certain coals which are peculiarly free from pyrites. There is no purer coal in this country than the thick coal of South Staffordshire. Its great value arises out of its extreme purity, and that purity is attributable to its freedom from pyrites. That it is free from pyrites must be evident to every one who has observed its combustion. The ash is as white as the ash of wood, and the shales interspersed in this coal, if subjected to the action of the fire, do not burn brown, which they would do if they contained any appreciable quantity of pyrites. Now, spontaneous combustion, I am fully prepared to state, arises in one class of coals only of a peculiar chemical composition. All coals may be divided into certain classes, although there may not be any very well defined lines of demarcation between the classes. Coal varies by imperceptible degrees, forming first the class called lignite, extending through the free-burning coals, such as those of South Staffordshire; thence passing into the more concentrated descriptions, or caking coals, and ending at the other end of the scale of classification with anthracite. Now, the various changes which have produced these different descriptions of coal are metamorphic in their nature, and are manifested by the gradual elimination of the gaseous elements. Most of these elements are nearly absent in those varieties of coal which form the lower end of the series, but as the coal approaches towards lignite, it contains a much larger proportion of oxygen. I am not able at the present moment to state the exact mode, in a chemical point of view, in which the different constituent elements of coal are associated with each other, but when gentlemen who are

acquainted with the various classes of coal which are more peculiarly liable to spontaneous combustion, come to examine the nature of its chemical composition, they will find that there is no coal which is liable to spontaneous combustion, except that in which a large amount of oxygen enters in composition, and this will be found to be the first class of coal that has departed from the lignite. When coal becomes more and more metamorphic, the oxygen is the first element which is eliminated, and it is lost, in a great degree, before the coal becomes of a caking quality, and then it is no longer liable to spontaneous combustion. I think no coals but the very free-burning coals are liable to spontaneous combustion; I believe no caking coals are ever found which are liable to it. In consequence of a certain degree of metamorphic action, coals become so far deprived of their oxygen as to become caking, and in that state they scarcely contain any oxygen whatever, and the coal is no longer liable to spontaneous combustion. I apprehend, from these circumstances, that it is clearly from the decomposition of the coal itself, promoted by the oxygen which is chemically combined in some manner or other with the other elements contained in the coal, which is the cause of spontaneous combustion in coal mines, and that the chemical decomposition, which is the cause of it, is incited and brought about by the presence of atmospheric air. It is a very curious subject, and I am not able to state, with sufficient accuracy, the chemical action which does take place, and which leads to spontaneous combustion. It would appear that the carbon in certain coals is in a state producing a tendency to unite with oxygen; and I think, that when the question is fully entered into, and the attention of chemists has been properly directed to it, it will be found that it is only this class of coals abounding in oxygen which are thus liable to spontaneous combustion. That spontaneous combustion results from the decomposition of the coal itself, by the action of oxygen, will, I think, be clear, when it is recollected that coals having that tendency produce large quantities of carbonic acid gas.

Mr. MATTHEWS—I cannot altogether agree with my friend Mr. Blackwell in the theory which he has offered for your consideration, in respect to the decomposition of the coal itself being the main cause which leads to spontaneous combustion. Mr. Blackwell has laid down the axiom, which I believe is generally admitted, that the decomposition of pyrites existing in the coal, but which is not one of the constituent parts of the coal, gives out the gas which spontaneously fires.

Mr. BLACKWELL—No; you have altogether misunderstood me. I

laid down no such theory. I stated that it was the generally received opinion, but I controverted that opinion.

Mr. MATTHEWS—My friend certainly alluded to the decomposition of pyrites as being a received cause for spontaneous combustion, and whatever arguments may be advanced to the contrary, I certainly think that the greater number of cases of the spontaneous combustion of coals have been attributed to the decomposition of pyrites. Whether that opinion be a correct one or not is another question. I simply state it as a fact; and I think it will be found to be the rule that spontaneous combustion arises from that cause, and that although there may be some other causes, yet that they form the exception. We know that pyrites may be mechanically combined with the coal, or that it may be more intimately or chemically mixed up with it. In the case of mechanical combination, it is quite evident that where you leave a mass of coal, containing a considerable portion of pyrites, to the free action of the atmospheric air, spontaneous combustion takes place very rapidly indeed. I recollect very well some years ago, that when I was engaged in forming a collection of the various strata of coal measures in the North of England and other districts, I took a portion of coals, and carefully wrapped them up in a paper, labelled them, put them into a cabinet, and forgot them. Two or three years afterwards, when I opened the cabinet I found that more than half of the coal, probably two-thirds of it, although it contained very little pyrites, was not only decomposed and disintegrated, but that it had burnt all the paper in which it was wrapped. On examining that coal, I found that there was a certain amount of pyrites either mechanically mixed up with the coal or chemically combined with its constituent elements. Whatever other causes, therefore, there may be which may lead to spontaneous combustion, it is a clear proof that the decomposition of the pyrites was, in this instance, the cause of the spontaneous combustion. Mr. Blackwell has informed us that a free-burning coal, or, in other words, a highly oxygenated description of coal, is more liable to this sort of spontaneous combustion than any other kind of coal. Now, I think I can mention one exception to this rule, if it be a rule, and that is the Brooch coal of South Staffordshire. That is a remarkably pure coal; it burns with great rapidity, and leaves a less quantity of residuum than any coal with which I am acquainted. Yet I happen to know that that very coal, possessing all those characteristics which Mr. Blackwell described as peculiarly appertaining to coal which was more liable to combustion than any other class of coals, is remark-

ably free from any liability to spontaneous combustion, whereas the thick coal, which contains a very considerable portion of pyrites, is found to be very liable indeed to spontaneous combustion. Anybody who is at all conversant with the working of the seams of thick coal in Staffordshire, must be well aware that, under any circumstances, a very small portion indeed of the course can be kept open, owing to the decomposition of the coals, which arises from the circumstance of their containing pyrites; and the general opinion among mining engineers and others is, that spontaneous combustion arises from the decomposition of pyrites. I must say that I strongly concur in that opinion. There cannot be any doubt whatever of the importance of the information which is contained in the paper that has been read to the meeting, especially that portion of it which has reference to the causes to which spontaneous combustion is attributable. It must be evident to any one that, before you can derive any proper and efficient remedy to prevent the recurrence of the evil, we must find out with some degree of certainty what it is caused by. Not only in the working of the coal does spontaneous combustion arise, but wherever any quantity of the coal is thrown, when it is exposed to the atmospheric air decomposition immediately begins to take place, and spontaneous combustion ensues. The inference which is naturally to be drawn from that is, that spontaneous combustion must greatly interfere with the working of the mine. I must candidly confess that at present I cannot see that any satisfactory cause has been assigned. If it is not to the presence of pyrites, to what other cause is it to be attributed? Perhaps it is, after all, more a chemical than a mechanical question; and if so, I should be most happy to hear the opinion of any gentleman who is more acquainted with the chemical portion of the question than I am. In fact, I should be delighted to have the opinion of competent authorities on this most abstruse and difficult of subjects.

Mr. GREENWELL—We all know that there are many vegetable substances, such as flax and other kindred materials, which, if packed together and exposed to atmospheric air, become liable to spontaneous combustion. It may arise from the presence of some chemical element intimately connected with coal and other vegetable products in a certain chemical condition and exposed to certain chemical influences.

Mr. BIRKENHEAD—I believe it has been generally considered hitherto that coal is a mineral in which carbon, hydrogen, and oxygen, with a little nitrogen, are combined. It must, however, be remembered, that the wood from which the coal is derived originally may be of many

different species, containing, perhaps, the same constituent elements, though in a different degree, and possessing different properties. Some of these properties might tend to produce certain chemical changes in decomposition more readily than others. May it not be the case, that in the mineral coal there are present a great many other substances intimately mixed up together, some of which are liable, in the course of decomposition, to spontaneous combustion, while others are not. Thus certain descriptions of coal may have a preponderance of combustible elements while others do not possess them; and yet all these different descriptions of coal may furnish, in the aggregate, almost precisely the same analysis. It may, therefore, be a question, supposing that spontaneous combustion does not arise from the decomposition of pyrites—whether it does arise from that or not is another question entirely—but, assuming that it does not, it may be a question whether those coals which are of an inflammable character do not contain a preponderance of certain constituents of an inflammable nature which is absent in the coal which is not specially inflammable, and yet that the two specimens of coal may, in the aggregate, furnish the same amount of carbon, hydrogen, oxygen, and nitrogen. With respect to the question of the decomposition of pyrites being the chief cause of spontaneous combustion, it has been observed, by Mr. Blackwell, that many descriptions of coal which contain a large amount of pyrites are not spontaneously inflammable. It must, however, be remembered, that there are several descriptions of pyrites not very readily distinguishable by the eye; and it was generally supposed that some of the varieties of pyrites are very liable to spontaneous combustion in the process of decomposition, while others do not possess, except in a very trifling degree, the same liability. Hence it may happen, that the coal which contains the combustible pyrites may lose its appearance of impurity, while that which contains a large amount of that variety of pyrites which is not combustible may present a remarkable appearance of the pyrites, accompanied by the usual indications of their presence in the production of a brown ash, and in various other respects betraying that presence. I did not understand Mr. Matthews's distinction between coal which contains pyrites chemically combined with it and coal containing pyrites mechanically mixed with it. I am not aware that chemists understand any chemical union to exist between pyrites and coal, and I think it probable that in nearly all cases the pyrites have been introduced into the coal a very long time after it has been formed.

Mr. MATTHEWS—I cannot quite concur in the ingenious doctrine which has just been propounded by Mr. Birkenhead, with reference to the introduction of the pyrites long after the formation of the coal. If we examine the laminæ of coal in which there is pyrites, we shall find that it is so mixed up with it that it must lead us irresistibly to the conclusion that it was formed at the time the coal itself was formed. In other cases where it is not so intimately blended, it may be the result of infiltration, but whenever it is combined in the form of laminæ, then I consider that it must have been formed at the time the coal was formed, or nearly coincidently. With respect to the distinction which I drew between the chemical combination of pyrites with the coal and the mechanical mixture, I think the distinction is a perfectly proper and just distinction, seeing that in some instances the pyrites take the laminal form, and in others that of nodules or compact masses, mechanically distributed in the body of the coal.

Mr. GREENWELL—In support of Mr. Matthews's theory, I could mention more than one coal bed extending over a very large area, where an examination of the coal must convince any one that the pyrites are a part of the original formation, or were formed shortly after the bed.

Mr. BLACKWELL—Perhaps I may be permitted to make a few remarks in explanation of what I said before, and more particularly with reference to what Mr. Matthews has said. In the first place, I did not attribute the spontaneous combustion of coal in mines to the presence of the pyrites at all. I attributed it in all cases to the peculiarly oxygenated composition of open-burning coal which exists before coal becomes so concentrated as to form that more metamorphic description which is known as caking coal. Caking coal contains only a small part of the oxygen which once existed in it, and anthracite coal contains so small a quantity of oxygen as to be almost inappreciable—perhaps one or two per cent. But the free-burning coal which is so liable to combustion, such as the thick coal of Staffordshire, the Moira coal and several other descriptions of coal, contains as much as sixteen or seventeen per cent. of oxygen, and I apprehend that there exists some peculiar condition in that coal, which, when it is exposed to the action of the atmospheric air, renders it thus peculiarly susceptible of spontaneous combustion, in consequence of its tendency to chemical decomposition. With respect to the decomposition of pyrites which may exist in the coal being the primary cause of spontaneous combustion, although I admit that in some cases it may be a secondary or extraneous cause, I must again appeal to

the fact, which I consider a very strong one indeed, that there is no appreciable quantity of pyrites either in the thick coal of Staffordshire or in the Moira coal-bed, notwithstanding which spontaneous combustion takes place in both. They are both white ash coals, and if there were any appreciable quantity of pyrites in them, it would be at once evident from the brown colour of the ash when the coals are burnt. All coals which contain a large quantity of pyrites burn to a brown ash, and pyrites cannot exist in coal without its becoming distinctly evident upon its being burnt. I think all gentlemen who have examined the different coal seams in this country will agree with me when I lay down the principle, that in no cases are caking coals liable to spontaneous combustion under any circumstances, or under any conditions whatever. As I have said, and as I repeat again, those coals which are more peculiarly liable to spontaneous combustion, are the open free-burning coals, like the thick coal of Staffordshire and the Moira coal; but the caking coals are not thus liable. We know that a highly oxygenated coal flames very much, and burns away very rapidly, not caking in the slightest degree, and I believe there is no instance of spontaneous combustion taking place in any other than these very free-burning coals. In all highly oxygenated coal, as far as my experience goes, spontaneous combustion takes place, whereas in caking coals no spontaneous combustion takes place. Taking these two facts together, I think that they afford conclusive evidence that spontaneous combustion arises not from the decomposition of pyrites, as has been generally imagined, but from some special condition in the coal itself, which does not exist after it has been subjected to metamorphic change, and my opinion is, that this quality or condition permits the decomposition of the coal itself to take place, but that in the other case the absence of the particular condition existing in the former case, prevents the coal from becoming liable to spontaneous combustion.

Mr. Woodhouse—Gentlemen, I assure you that it is with extreme diffidence that I venture for a moment to differ from so high an authority upon this subject as my friend Mr. Blackwell. I wish, however, to offer one or two observations with respect to the coal of the Moira coal seam. I may at once say that, with respect to the thick coal of Staffordshire, although I am acquainted with it from casual observation, I have not studied its character with such a minute degree of attention as to justify me in offering any positive expression of opinion with regard to its constituent elements, or, rather, I should say its component parts. Mr. Blackwell will, however, I hope, permit me to correct him upon one

important point which he has referred to more than once during the present discussion, and relied upon as one of the strongest in favour of the line of argument he has taken. Mr. Blackwell has assumed throughout the whole of his argument, that the Moira coal seam produces a highly oxygenated coal, free from pyrites, and burning to a white ash. Now, so far from the Moira coal being a white ash coal, it is essentially a brown ash coal; and all that part of the Moira coal-bed which produces a white ash coal (for I am free to confess that a portion does so), is entirely of a secondary character. Some of it burns to a white ash; but of the presence of pyrites in the Moira coal there is no question whatever. I do not happen to have the analysis with me, but I know the quantity of pyrites is very large. Its presence may be perceived in the upcast shaft, and it is sometimes found in large lumps, which we have tried to sell to the chemists. On some occasions they come to the mine and buy it freely, but on other occasions it is not so much in demand, and they will not have it at all. There is a large quantity of it collected. What the analysis is, I am not prepared to say. At the same time, I may mention that, in some of the mines in the county of Derby, there is a large quantity of pyrites taken out of seams of coal, while in those particular mines there is no trace of spontaneous combustion at all.

Mr. BLACKWELL—Will you inform me, Mr. Woodhouse, whether the Moira coal, of which you are speaking, is a *non-caking coal*, as is the case in Derbyshire, and whether that portion of the coal which is not *non-caking* is not a portion that is most subject to spontaneous combustion in the mine?

Mr. WOODHOUSE—I am speaking of the top hard seam, which is essentially a non-caking coal, and which contains a large quantity of pyrites of iron. But there is another seam in the Derbyshire coal-field, called the black shale. That is the lower seam, and that also contains a large quantity of pyrites of iron.

Mr. BLACKWELL—And that, I presume, is a *caking coal?*

Mr. WOODHOUSE—It is essentially a *caking coal*, and is *not* subject to spontaneous combustion. The Moira coal generally is very liable to spontaneous combustion.

Mr. BLACKWELL—With regard to the hard coal of Derbyshire, it partakes, in some degree, of the nature of cannel coal. Cannel coal contains about half the amount of oxygen compared with the thick coal of South Staffordshire, and cannel coal does not ignite spontaneously. It does not take fire spontaneously; that is to say, it does not decompose in

the same manner as the other descriptions of coal of which I have spoken, and burn by spontaneous combustion. It seems to exist under a different chemical condition, which, in common with the hard coal I have alluded to, takes it out of the category of the spontaneous burning coal which I have endeavoured to establish.

Mr. Woodhouse—With respect to that point, I may mention that the hard coal of Derbyshire does not very much approach the stratification of the cannel coal. There is no question at all about that, and every one can satisfy himself by an examination. In reference to spontaneous combustion, several of the mines in the North of England are troubled with it, and I should be glad to hear some explanation given which bears special reference to them. In regard to the diagram, I was asked a question, in the early part of the day, as to the mode in which we prevent spontaneous combustion, and as to the effect of the passage of a strong current of air through those portions of the mine in which it is liable to occur. I stated broadly then, that it was perfectly practicable to work a part which was subject to spontaneous combustion with the air passing through it in a considerable volume. In this particular colliery, which is not a very large one, the whole extent of the facing being about 400 yards, the volume of air which runs through here [pointing to the plan] is between 20,000 and 30,000 cubic feet per minute. It is in this particular spot that there is the greatest liability to spontaneous combustion. From here to there [pointing to the plan] represents a considerable distance, although it appears to be inconsiderable upon the plan. Then there is a long inclined plane of about 600 yards in which the fire-damp is given off very freely. The gradient here will be about one in five, caused by a series of throws. It is necessary to cut through these throws, and it is at this point that there is shown a split, which comes off in this direction [pointing to the plan]; draughts are put in here and there. There is a course put down here, and it runs along in this way. The current of air is directed by these doors. It runs through by the split on to that face. It then turns down here, runs along in this direction, and then both currents come together and cross down into the return air-course, so that the upcast split runs along in this direction and is shut off by these doors, then joins the other and so returns along the upcast main current. The whole of that current is between 20,000 and 30,000 cubic feet, and it is so strong along that face that it is almost impossible to keep a light unless there is some kind of shade over it. In this portion of the mine there is a very large quantity of explo-

sive gas, and when the barometer falls, and the wind is in the south, it is tremendous. It comes away in gusts, and the barometer is a sure indicator of the quantity that is accumulating. There are particular times, such as the break of roof, when it gives off the largest quantity. The whole of these passages are then charged with gas, and the waste-man knows very well what to do with it. Notwithstanding all this, we can work the face with a naked light. The plan we adopt, and which we find to be the only practicable one, is to exclude the air from running into the goaf roads and courses. What Mr. Matthews referred to sometimes occurs. By a little pressure upon this part [pointing to the plan] the coal is split, and slack or fire-clay gets into the crevices, which, when the air runs through, fires almost immediately. Of course it is a source of continual danger, and requires very great attention, but the people who are constantly in the mine can always deal with it. The late Mr. Robert Stephenson expressed considerable doubts as to whether it could be dealt with; but experience has shown that it may be dealt with with comparative safety. As to the question of spontaneous combustion arising from the decomposition of iron pyrites in the coal, or from the decomposition of the coal itself, that is a very interesting question indeed, and I hope that some gentleman well acquainted with the chemical character of the coal in the different districts will, on some future occasion, be able to throw some light upon it, because, I can assure the meeting, that the gentlemen in the North of England are exceedingly desirous of investigating the whole matter, and are ready to take any steps which may be likely to reduce the extent of the evil to which they are constantly subjected.

Mr. BLACKWELL—In the case which you have mentioned, where gas accumulates along the face, and where there is a large current of air, I suppose the face is constantly being shifted?

Mr. WOODHOUSE—Yes.

Mr. BLACKWELL—The air does not go over the same face any long time?

Mr. WOODHOUSE—No. It is moved twice or three times a week.

Mr. ATKINSON—I am not aware that spontaneous combustion occurs in the mines in the North of England; but the large heaps of refuse coal and pyrites on the surface in many instances ignite spontaneously.

Mr. BLACKWELL—In the goaf or waste, where there are accumulations of slack or small coal, may not these, if exposed to a current of air,

take fire spontaneously? May not the comminuted state of this coal cause the air to act upon such small coal in a more energetic manner than it does in other instances on this coal, before it is worked and reduced to small?

Mr. Boyd—I will give one more example of the decomposition of pyrites in a mine giving rise to spontaneous combustion, occurring in a colliery near Berwick. In this case, the combustion took place at a very considerable distance from the face. It is the occasion of unpleasant heat in the mine, and upon inquiry of one of the managers as to the cause, he informed me that it always occurs where they are "bigging the gob," and when the material stowed is mixed with iron pyrites. When the iron pyrites decomposes, the gas is evolved, and they cannot get rid of it without increased ventilation around it.

The President—That is not a caking coal?

Mr. Boyd—No. It burns to a brown ash, but it does not cake well.

Mr. Daglish—I know also of some instances of pits taking fire which contain iron pyrites.

Mr. Blackwell—Are they pits containing bituminous or caking coal?

Mr. Daglish—Yes.

Mr. Greenwell—There was a case of spontaneous combustion at Killingworth.

Mr. Stuart Smith—In the Warwickshire coal-field, where we were troubled with spontaneous combustion, it was always said that a great quantity of air, decomposing the shale and pyrites in the goaf, was one great cause of spontaneous combustion. I found, however, in practice, that introducing a larger quantity of air along the edges of the goaf, so as to dry up the moisture coming from the mine and goaf, tended rather to diminish spontaneous combustion than otherwise. It appeared that wherever the moisture got mixed up with the iron pyrites and shale in the waste, decomposition ensued, which tended in a great measure to cause spontaneous combustion.

Mr. Handel Cossham—In our collieries, in which the coal is of a highly bituminous character, we are so subject to spontaneous combustion, that we are obliged to extract the whole of the slack out of the mine. If we leave the slack behind at all, spontaneous combustion takes place directly. That coal, as I have said, is of a highly bituminous character, and we can only account for the spontaneous combustion taking place in consequence of the presence of a large quantity of pyrites, and

as a further proof that this is the case, I may remark that the same coal when worked (which has the effect of taking out most of the pyrites) will not so readily ignite spontaneously.

Mr. BEALE—No doubt the presence of pyrites is, to a great extent, the source of spontaneous combustion. I know a case in which ironstone, containing pyrites, had been thrown out into heaps, and it took fire in consequence of the action of the water and the air together. I do not think it is to be doubted for a moment that sulphur will be the result of the decomposition of pyrites, although it is perhaps possible that spontaneous combustion may proceed from one cause or the other, or from the operation of both together.

Mr. EVANS—In South Wales only one case of spontaneous combustion has occurred underground for many years past, and that was in a slightly bituminous seam. The steam coal when exposed to the weather in large heaps often takes fire, but as a general rule, the coals containing the most pyrites are not the most liable to spontaneous combustion; possibly, therefore, it may be due to some other cause as well as to the presence of pyrites.

Mr. ATKINSON—In reference to Mr. Evans's remark, I may say that stone coal is very difficult to set on fire, and requires a good deal of care and coaxing to keep it burning even after it is ignited, so that one could scarcely expect it to take fire spontaneously, under any conditions.

Mr. EVANS—There is no doubt of the accuracy of what Mr. Atkinson has just stated; but, to extend it still further, that observation may be applied to the case of steam coal. I have known that coal set aside in large heaps, and, although it contained a quantity of pyrites, it never generated spontaneous combustion. The only case I know of is one of a very slight character which occurred in Glamorganshire.

Mr. DICKINSON—I am very happy in having heard so much light thrown upon this abstruse subject. I hope eventually that we shall be able to get at the causes of spontaneous combustion. All those who have anything to do with mines in which it occurs, must know how exceedingly troublesome it is. I do not know anywhere a more dangerous thing in colliery operations than to undertake to go down the shaft for the purpose of extinguishing a fire. Indeed, where there is a very large quantity of fire-damp surrounding the fire, it becomes an exceedingly difficult and dangerous operation, for the moment any fresh air comes near an explosion is liable to take place. Several cases of explosion of this character have come under my notice. I should like

to hear the opinion of practical men who are informed upon this subject, as to what they consider the best way of extinguishing such fire, and whether they resort to deadening it or to shovelling it, and what process has been found to answer best for extinguishing a fire?

Mr. DARLINGTON—I wish to call Mr. Blackwell's attention to one fact in connexion with caking coal. I would instance the Ince Hall Colliery, near Wigan. In that colliery the Arley seam is entirely cleared out, and the slack brought to the surface of the mine. When the small coal is exposed to the action of the atmosphere, the heaps of small which are accumulated and left in the open air will certainly take fire. The Arley seam is a caking coal. I am not sure whether it is not to some particular influence to which the coal is exposed as much as to the inherent elements of the coal itself, that the firing is to be attributed. It is a singular thing that the coal left in the mine does not fire, and that it is only when the small is brought to the surface and accumulated in heaps that it takes fire. I am inclined to believe it fires in consequence of some preponderating gas caused by a chemical change. So long as the atmosphere is exposed to it in the mine that change does not take place; but when a large quantity of small coal is brought up and exposed to rain, wind, and sunshine, the heaps will certainly take fire. With regard to the enquiry which Mr. Dickinson has just made, as to what is the best way of dealing with a fire in a mine, my own experience is, that the best thing is shovelling it out altogether, if it is possible to do so; but where that cannot be done, cover the gob face with sand or clay and exclude the air. That would be the simplest mode of proceeding.

Mr. WOODHOUSE—That is the present mode of dealing with fires of this kind, but there are not many fires that are got completely out in that way. They commonly occur in the inbye. The state of the clay wall where the current comes over it is the first indicator we have of the presence of fire. Moisture settles on the roof, and the heat throws out steam, which gradually finds its way down the cracks, and comes into contact with the fresh air running through the main road. The moisture is condensed and hangs on the roof in drops, and so sure as we observe that indication so sure may we be that fire is generating. As soon as we perceive by these appearances where the fire is we immediately proceed to scour it out. Sometimes we find that the fire has extended to nine or ten chains. It gets quite red hot, so that we have had to get the fire engines down and play upon it, and I can assure you that playing upon a fire in that position is no joke at all. We then set to and clear it out,

and when that is done we fill the space up with sand and other stuff, which is found to be better than any other materials, and we then put the refuse back, because after it has been once burnt it is less liable to become heated again. We put up the packing which is burnt and face it off with clay. We keep the bottom well packed up so as to exclude all the air, and then there is an end of the thing, and nothing more takes place until the next fire occurs.

The PRESIDENT—Gentlemen, I am sure we must all have been very much gratified with the discussion which has taken place on this most interesting subject. Certainly it is a subject which is more applicable to this than to the northern district. Our experience in reference to spontaneous combustion is very limited, for I am happy to say that we have had very few cases of spontaneous combustion. The only well-authenticated case that I know of, is that which occurred at Killingworth, as mentioned by Mr. Greenwell. That was a case in which the mine was worked by the pillar and stall method, and the pillars of that day (about thirty-five years ago) were left extremely small. Several partial creeps had taken place between the packing up and the roof, which very nearly filled the spaces where the coal was taken out. A considerable quantity of small coal was left in the waste, in the old workings—probably about one-sixth of the entire mass of coal that was taken out—and in that state that portion of the mine was shut up for several years, during which time it became filled with water. We had occasion, recently, to take the water out, for the purpose of going into that district. When we went into it, we found it extremely warm—very much beyond what the natural temperature ought to have been; and in opening out the old workings further, we found masses of scoria, as compact as any metal, showing that there had been a fire there of very considerable extent. That certainly had, in my opinion, been caused by the decomposition of the pyrites which was mixed up with the small coal, which we had formerly been in the habit of leaving in the bords or stalls, and which, I have previously stated, was from one-eighth to one-sixth of the total quantity of coal worked. That is the only well-authenticated case that I have known where spontaneous combustion has occurred. The coal which has been alluded to is a free-burning bituminous coal. With respect to the steam coal of the north, I believe a large quantity of the small coal is left underground, but I do not myself know of a single case of spontaneous combustion of that coal. With respect to the opinions which have been expressed here to-day, they certainly seem to me to be

somewhat at variance with each other. What occurred to me, as to the chemical constitution of the coal in the Moira Colliery, and the statement made by Mr. Woodhouse that it was not a white ash coal entirely, but that part of the seam is a brown ash coal, is this:—I am inclined to suppose the brownness of the ash must be the effect of an admixture of iron. I believe that it is a general indication of the presence of iron in coal, when it burns to a reddish or brown ash. This shows that the seam, in its chemical constitution, contains iron, and is consequently liable to decomposition, although, generally speaking, it is an open-burning coal. On this subject I shall only further say, that I am glad that it has been brought before the Institute, and that it has been discussed in so able a manner by those gentlemen who have expressed their opinions upon it. The consideration of this subject forms one of the class of inquiries yet requiring further development, which I took the liberty of mentioning in my opening address to the meeting. It is a subject into which it will be necessary to go a great deal further. We must inquire more closely into the chemical constituents of the coal; and I hope that, after our attention has been thus directed to the subject, and after the lengthened discussion which has taken place, we shall, at our next meeting, be able to throw more light upon the question at issue, and probably ascertain, in the end, from what spontaneous combustion arises.

A vote of thanks was then unanimously given to Mr. Fowler for having brought the subject under the consideration of the meeting.

ON THE MODE OF WORKING

THE THICK OR TEN-YARD COAL

OF

SOUTH STAFFORDSHIRE.

By HENRY JOHNSON, Dudley.

The paper about to be read to the meeting is upon the mode of Working the Thick or Ten-yard Coal of this district, a subject I am afraid I shall but very inadequately do justice to; and as it is only a detailed and practical account that can be at all interesting or instructive to those mining engineers who reside at a distance, I hope my compeers who live in the immediate neighbourhood will bear with me if it should appear to them that I descend too much into particulars, and thus render it to them a "dry subject;" and also keep in mind, that the paper has not been penned so much for their edification as for the information of our visitors, whom, I think I may assure, on behalf of the mining engineers of this district, have our heartiest welcome on this occasion, and as it is by such meetings as the present that the scientific and practical principles of mining engineering are beneficially discussed, we may venture to hope it may not be the last gathering of a similar kind in this district.

To endeavour to make the subject comprehensive to you, I have divided it under the following heads:—

1.—Description of the seam. Names and thickness of each measure comprising it. Workmen's stints in each.

2.—Gaitroading. How formed. Stints, &c.

3.—Air-heading. How formed. Stints, &c.

4.—Opening the work. Bolt-holes. Getting the bottom coal. Cutting the top coal. Nature of floor and roof. Robbing the pillars. "Cutting in" at the bolt-hole. Damming up, &c.

5.—Opening new work.

6.—"Butties," or charter masters. "Doggies," or overlookers.

7.—Fire stink, or spontaneous combustion.

8.—Gases, peculiar to the district. Old method of firing it, and the introduction of top air heading.

9.—Produce of thick coal per acre. Produce of second working in ribs and pillars, and proportions of coals, lumps, and slack.

10.—Park Head section of thick coal, description of.

11.—Faults.

12.—Ventilation.

1.—*Description of the seam, &c.*—It, perhaps, will be well for me to give you, first of all, a description of the layers or beds composing the great seam of coal which forms the subject of the present paper, and in the order of its deposition.

As to the natural faces or cleavage of the different beds comprising the thick seam, I would observe that the natural cleavage of one bed is no criterion as to the direction or bearing of the one lying immediately above or below it. Crossing and re-crossing each other as they do, no regard is paid, or at all events very little, to the natural cleavage.

I think this incongruity of mineral structure very fortuitous, for if the natural cleavage or faces of the coal ran the same in one bed as in another, we should never get the pillars to stand and support the weight they are required to do. (See Section.)

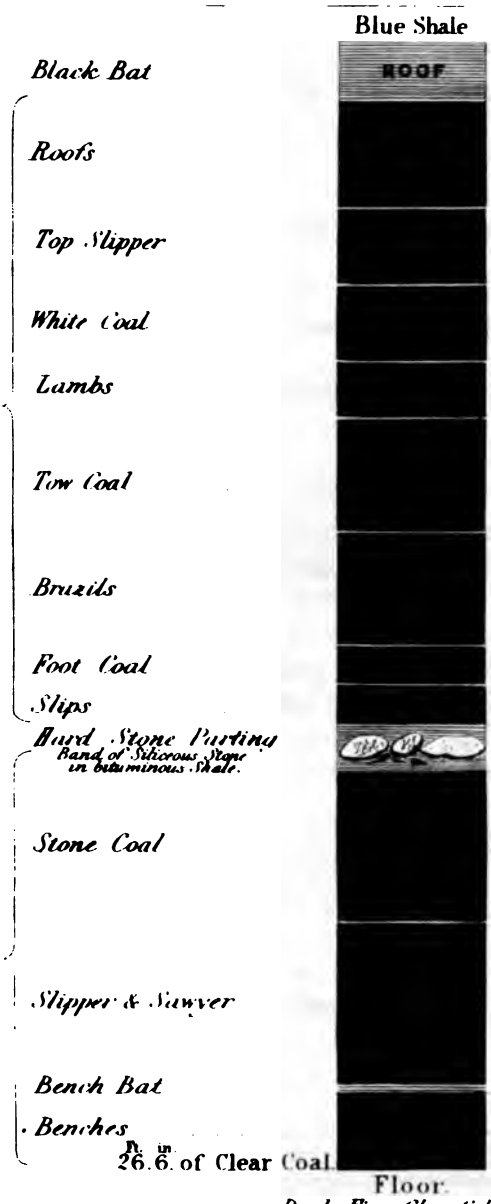
Having thus given you a detailed account of the nature and thickness of the various beds comprising the seam, I will now proceed to describe to you the first and successive operations of working away the seam.

The width of the shafts sunk in the South Staffordshire district on an average is seven feet diameter in the clear between the brick lining, which is universally four inches and a half thick, set in mortar, and the shafts are always circular, and not square or oblong, as is sometimes adopted in other mining districts, and they are sunk in what are called "pairs," one about ten yards apart from the other, no bratticed shafts being used.

2.—*Gaitroading.*—The two shafts being sunk through the seam (and a sump below when necessary), a "gaitroad" is driven from one pit bottom to a convenient and suitable part of the boundary (see plate II.), sometimes the extreme deep being preferred, whilst with some coalowners the nearest and cheapest possible route to the boundary is adopted, for the sake of a speedy return of the capital expended.

SECTION OF THE THICK COAL
—at the—
HEATH COLLIERY, WESTBROMWICH.
PILLAR & STALL.

This was the first Pit sunk through the New Red Sandstone in S. Staffordshire 1832. 300 yds. deep cost £28,000



		Thicknesses Ft. in.	Yard in the Cutting for a days work: Ft. in.	Sq. Feet for a days work. Sq. Ft.
	Black Bat	1. 6.		
Top Coal.	Roofs	2. 9.		
	Top Slipper	2. 0.	13. 6.	27.
	White Coal	2. 0.	13. 6.	27.
	Lambs	1. 6.	21. 0.	31. 6.
	Tow Coal	3. 0.	9. 0.	27.
	Bruzils	3. 0.	9. 0.	27.
	Foot Coal	1. 0.	21. 0.	21.
	Slips	1. 0.	21. 0.	21.
	Hard Stone Parting *Band of Siliceous Stone in bituminous Shale.*	1. 3.		
Bottom Coal.	Stone Coal	4. 0.	9. 0.	36.
	Slipper & Sawyer	4. 3.	6. 0.	25. 6.
	Bench Bat	0. 3.		
	Benches	2. 0.	6. 0.	36.
	Ft. in. 26. 6. of Clear Coal.			

Dark Fire Clay full of Stigmaria ficoides.

ale 5 Feet to an Inch.

ceedings N° of E.I. of M.E. 1861-2. (Birmingham Meeng.

This gaitroad is driven nine feet six inches wide, and, when completed, is about twelve feet high, which takes the benches, slipper and sawyer, stone coal and hard stone parting, and sometimes the slips breaking down, make the whole height about fourteen feet. During the driving of this gaitroad, an air-head for the purpose of ventilation is driven alongside, and five yards from the gaitroad, with "spouts" or "thurlings" about every fifteen or twenty yards, or much nearer, according to circumstances, each back spout being successively dammed up as the gaitroad proceeds. (See plate II.)

The pit bottom is usually bellied out a little, and the "inset" or pit eye made wider and higher than a common gaitroad. This being done, the gaitroad is proceeded with.

One workman, called a pikeman, holes away the benches and bench bat, about two feet three inches high, three feet six inches wide, and six feet in, for a day's stint, which is 3s. 6d., and is called a "head*;" whilst another man follows him, with two feet three inches high, six feet wide, and six feet in for a day's stint, which is also 3s. 6d., and is called a "pane;" or they will do what is called "throw their work together," and each take it four feet nine inches wide, six feet in.

This operation is proceeded with until ten or fifteen yards in length of holing is done, when cutting the slipper and sawyer is commenced, which will be presently explained.

During the driving of one-half of the ten or fifteen yards of gaitroading, a lad from twelve to fifteen is employed, with an iron rake and basket, to carry away the coals and slack produced by the two men, and his wages would be about 2s. 6d. per day of 10½ hours for 1½ days of the pikemen, and for the remaining distance two boys would be required to keep the dirt clear.

It perhaps may be as well here to state that the butty (charter master) finds these pikemen all tools, sharpening, candles, and two quarts of pit beer per day,† so that a good and quick workman who does two days' stint in a day, is a saving to the charter master both in candles and beer. These men go to work at six a.m., and will generally get a day's work done by twelve or one o'clock. The boys, during the "cleansing" of the slack from these two men, have their tools and candles found them by the butty, and are allowed one quart of pit beer each per day of 10½ hours.

* This 3s. 6d. three years ago was 5s. per day.

† This beer is supplied at 1½d per quart, and has been a custom from time immemorial; but only half this quantity is allowed in the other thin seams of the district.

After the holing, before described, is completed, two or more pikemen go under, to the far end, and at distances of six feet, measuring from the back of such holing, they commence and cut holes up-hill through the slipper and sawyer to the parting which lies under the stone coal, leaving "spurns" between each six-feet hole, and a sprag or two at the face, until the ten or fifteen yards are so cut, taking the precaution always to leave a spurn at the face where the holing commenced. This being completed, the spurns are reduced with the pike, and afterwards completely "jammed" out with a long stailed "pricker," as it is called, used for that purpose, until, when the face spurn is taken out, down comes the whole length so holed and cut, breaking off against the fast or uncut side, and it is then ready for the "turner's out" and "loaders."

The price these men are paid for cutting this six feet long and four feet three inches thick is 3s. 6d., and the allowances, &c., the same as in the holing. After these coals are loaded up and sent out, the breaking off side is then "set to" and trimmed upright, and forms the subject of a bargain of no little jealousy sometimes, being what is commonly termed "odd knobbing," or "light work."

The gaitroad, then, is seven feet high, and, generally speaking, if the stone coal was not got down it would break down unexpectedly, so it is cut off on one side, the same as the slipper and sawyer, and broken off on the other side, and with it, generally speaking, comes the weighty hard stone and its batty parting, and all or a portion of the slips (the latter without cutting). The stint in cutting the stone coal is nine feet long and four feet thick for a day's work, 3s. 6d., with the same allowances as in the holing. After the "setting to" on the breaking off side of the stone coal, the arching or rounding off of the roof in the slips, and the loading up of the produce is accomplished, the gaitroad may be said to be completed.

3.—*The Air-heading.*—The air-heading which communicates with the upcast shaft, and is intended to ventilate the gaitroad and the workings connected with such gaitroad, is driven three feet six inches wide and three feet high, or in some cases four feet by four feet, having the hard stone for its floor (at the Heath pit it is driven in the brazils) and taking in the slips and foot coal. It will, then, readily be seen that the roof of the air-head is on the same level as the roof of the gaitroad, and serves to ventilate it by the spouts or thurlings before mentioned in the most effectual manner, so long as the air-head is made the intake.

The stint for a pikeman in driving this air-heading is three feet six inches

high, three feet six inches wide, and four feet in for a day's work, 3s. 6d., with the same allowances as in the holing, and one lad in this case is reckoned to one pikeman, and in some cases two lads, according to the distance which the slack has to be carried and thrown through the spouts down into the gaitroad for loading up. As each successive spout is "thurled" the one previously made is stopped up with coal dust, and a four and a half inch or nine inch brick and mortar wall built across and made air-tight, which is termed a dam.

4.—*Opening the Work.*—The gaitroad and air-head having been completed to or near the boundary, the next operation is that of opening the work, which is done by pillars and stalls forming "sides of work" or chambers, of from two to twenty pillars in each side of work, varied according to circumstances. But in the present instance we will confine our observations to a side of work of four pillars, being what would be termed in common parlance "a nice little side," which, if successfully wrought, would produce about 15,000 tons. The pillars would be about nine yards square, and the stalls and openings ten yards wide.

We will suppose, then, that plate II. represents such proposed side of work, and the gaitroading and air-heading already driven, and the seam lying tolerably level.

Bolt-holes.—The first operation then would be to drive two bolt-holes, A and B (plate II.), as they are called, out of the gaitroad, the same width and height, and in the same way as the gaitroad, either at right angles with the gaitroad, or obliquely, as shown, for fourteen yards in length, when a head, three feet six inches wide, and two feet nine inches high, would be driven in the "benches" from bolt-hole to bolt-hole, which would be termed "thurling the bolt-holes," and would serve to ventilate them, and open the work. Large wooden boxes, or "air trows" (troughs), would be placed across each bolt-hole, to restore the air current after the bolt-holes had been driven.

Getting Bottom Coal.—This completed, the middle stall C would be commenced holing in the benches, in the direction of the dotted lines, for nine yards, and the opening between the two bolt-holes, would also be holed by virtue of the bolt-hole B. Then the "slipper and sawyer" would be cut off the inside rib between the two bolt-holes, and partially off the front of the pillar F. The holing would be done by pikemen in this case, taking six feet wide each and six feet forward for a day's work, which are called "panes," and the slipper and sawyer would be cut in lengths or holes of six feet long, and four feet three inches thick.

Whilst this holing was being done, small "cogs" or "packings" of refuse would be made here and there under the holing, and the face of the hanging coal propped with short puncheons, according to circumstances.

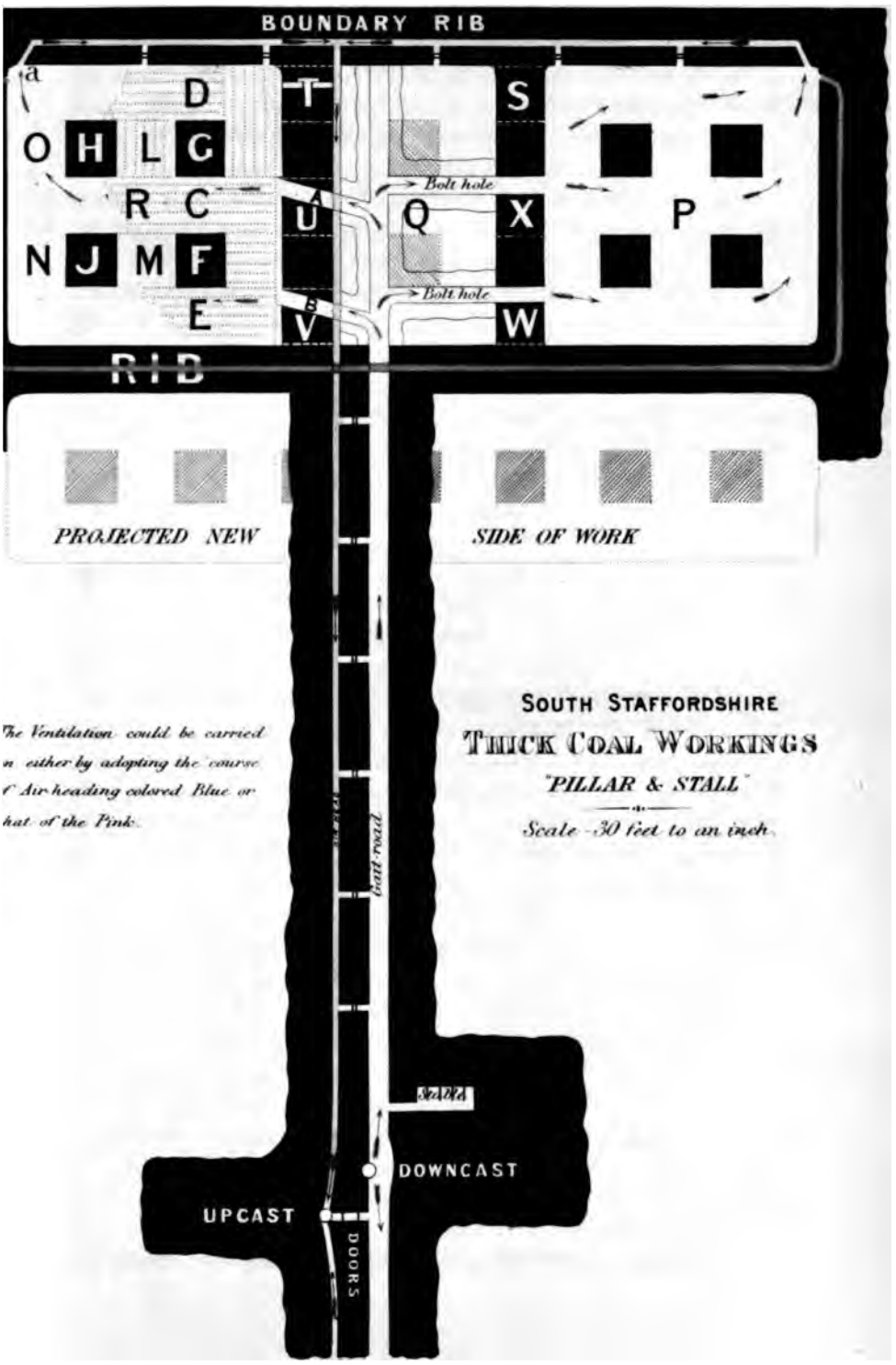
After the cutting of the slipper and sawyer before mentioned, the spurns left between each hole or cutting are reduced by the pike, as far as safe to do so, and are afterwards completely jammed out with what is called a "pricker." The cogs underneath being at the same time jammed out, and the puncheons knocked away from the face of the coal, they not only bring the slipper and sawyer down, but all the measures up to the bottom of the "brazils," the top coal still hanging.

This bottom coal is then ready for loading up and sending away, which is done by what are called "bandsmen," at 4s. per day of 10½ hours, or stinted to load twelve skips for a day's work, each having about twenty-five cwt. of coals upon it, or fifteen tons per day, the men laying the rails up to the face of the coal as the coals are loaded up. The "hard stone" and its parting, together with any other rubbish, is carried and thrown alongside the rib or pillar, and afterwards levelled down underfoot, which, when it has attained some feet in thickness, proves a fruitful source of spontaneous combustion, which will be hereafter treated of under the head of "fire stink," a word which is not a misnomer, for the appellation is very forcibly developed in the "fire" and in the "stink."

The next operation is to get the holing out as quick as possible along the face of the pillar G (plate II.), and proceed with the stall D in the same way as before described. Then the stalls D, C, and E are carried forward in the same way to the back rib K, taking the openings L, M, N, and O through from stall to stall as the work proceeds. The bottom coal being drawn out in the right hand stall D, and the air-head spout being driven into the back corner at *a*, the next operation is to begin to cut the "top coal."

Cutting the Top Coal.—If the "slips" and "foot coal" have previously broken down, and been loaded up, the first operation would be to "set" the sides of these measures "to," making them and the whole thickness of the bottom coal in the rib as upright as a wall. Then the "brazils" would be cut in holes of nine feet long and three feet thick for a day's work, and by cutting them all along the back of the pillars H and J, and off the rib K, it will be seen that, by "jamming out" and weakening the "spurns" left between each hole of cutting, that this yard thick of coal, ten yards wide and forty-eight yards long, would come to the ground

PLATE II


BOUNDARY RIB
a
D
T
S
O
H
L
G
R
C
U
Q
X
P
N
J
M
F
E
V
W
Bolt hole
Bolt hole
RIB
PROJECTED NEW
SIDE OF WORK
The Ventilation could be carried
in either by adopting the course
of Air heading colored Blue or
that of the Pink.
SOUTH STAFFORDSHIRE
THICK COAL WORKINGS
"PILLAR & STALL"
Scale -30 feet to an inch.
Main
Haul road
Staple
DOWNCAST
UPCAST
DOORS

and be ready for loading up, and could be reached for loading up by the three stalls D, C, and E. The top coals are cut by the pikeman setting up a scaffold, which is done by cutting two holes in the solid coal at the proper height, and putting in two short "byatts," on which he places a plank to stand upon; or, it is better done by leaning two poles against the side, and two short lashing chains lashed near the top of each pole, and a hoose made to receive each end of the plank.

As the "brazils" would be cut and brought back towards the bolt holes by successive cuttings around the four pillars, so would the "tow coal," or the "lambs" and tow coal, be cut off the back rib and brought back in the same way as the "brazils," and so on with the "white coal," and afterwards with the "top slipper." The back intake spout *a* (plate II.) of the air-heading is sumped up or raised as the different measures are cut away, so that no recess is formed for the accumulation of gas.

After the "top slipper" is cut and drawn out the roofs are, in the words of the collier, said "good bye to," and never expected to be obtained, but sometimes they break down of their own accord, without the superincumbent strata following, and then no time is lost in getting them out of the way. The side of work or chamber would now have more the appearance of a coal quarry than a coal pit.

I would here observe, that it is not always the case that the "bottom coal" is got out in the uniform progress, or that the "top coal" is cut in towards the bolt hole in the order previously described, much depending upon the nature of the demand for the *different qualities* of the coals. Generally speaking, the "top coal" is commenced to be "cut in" before the "bottom coal" is all cleared out nearest the bolt-holes, in order to mix the different qualities to meet the varied requirements of the trade.

In cutting the "top coal" in large sides of work where there is great demand, *cuttings* of two measures, making together six or eight feet thick, round four or five pillars, are made, and large quantities of coal are thrown together, as much as 2000 or 3000 tons at one drop. But it will be understood that this can only be accomplished where you have a sound and good coal, with a good roof.

Roof and Floor.—Both the roof and floor of the thick coal vary considerably, and either one or the other, if of an unfavourable character, as a matter of course influences not only the size of the sides of work, but the width of the openings and size of the pillars and cost of getting, &c.; as, for instance, a gaitroad in the "Park Head thick coal" would stand better for seven years than one in the "West Bromwich coal"

would for seven months, the floor of the latter creeping very considerably in some parts of that district.

"*Cutting in*" *at the Bolt-hole.*—By the time the "top coals" are "brought back," and pretty well thinned over the "bolt-hole," then comes a precarious operation, as the name of that *outlet* implies, for never was an aperture more rightly designated. On the finishing of a side of work, by looking up over the mouth of the "bolt-hole" you will see some known, good plucky workman perched upon a scaffold, some twenty feet from the ground, cutting the last remnant of "white coal," or "top slipper," listening almost breathlessly, at every blow of his pike, if the "coals stir;" when he hears it begin to stir, he manages to scramble down and get safe into the bolt-hole, just as the falling coals sometimes scrape his heels.

Damming.—After the side of work is thus finished, a refuse dam is put in the bolt-holes and in the air-head, and a good strong brick and mortar wall put on the wind side afterwards. The brick dam is put deep into the floor, sides, and top of the bolt-hole, and is intended to hermetically seal the side of work just finished. This precaution is taken immediately the last coals are drawn out, otherwise spontaneous combustion of the refuse slack would ensue.

5.—*Opening of a New Side of Work.*—Whilst this four pillar side of work is being "cut in," another side of work P would be required to be started in the bottom coal, and by the time that side was nearly exhausted, the small side of two pillars Q could also be started, leaving ribs between P and Q and Q and R, or P and Q thrown into one, or P, Q, and R all thrown into one, by making openings through the ribs at S, T, U, V, W, and X. This extension of the area of the work would, of course, depend upon many circumstances:—the relative state of all three "sides of work" as regarded "fire stink;" accumulation of explosive gas or carbonic acid; and the demand for coals, at the time when the side of work Q was being "cut in." With a *quick trade*, and *all* other circumstances being *favourable*, the original side of work of four pillars could be thrown into one of fourteen pillars readily and economically. (See plate IV. for plan of an extensive area of actual workings.)

Robbing the Pillars.—It is often the case, that when the pillars begin to "sos," or, perhaps, in more intelligible terms, begin to sink into the floor, under the immense pressure of the overlying strata, they split or crack from top to bottom, sometimes cornerwise, at others parallel with one of its sides, when one or two days' work with the pike, assisted by a

little powder, will bring off 100 or 150 tons of fine large coals. This I have termed "robbing the pillars," fearing to use the local term in the presence of so large a meeting.

I would observe, that the principle of working previously described is not adopted throughout the whole of the coal-field, but necessarily varies according to circumstances. In some cases the stalls and openings are not taken more than seven or eight yards wide, and the pillars five or six yards square, whilst in others "cogs" are cut off about six or eight feet square in the middle of the stalls and openings, and afterwards entirely holed out when the top coal is to be gotten. In some cases, what is called a "man-o'-war" is left as an additional support, which means a small auxiliary pillar, having some especial service in regard to a faulty roof.

In some half dozen collieries the thick coal is being worked at twice by "long wall," or which, perhaps, from the thickness got out at each working, would be more accurately described by calling it a "long wall modification of pillar and stall." Great advantages are claimed for it by its several adopters, but I have deferred further particulars of its working, as it ought to form the subject of a paper from some of its supporters.

6.—*Butties or Charter Masters.*—The prevailing mode of raising thick coal in this district is, by what is termed "buttyship," which is a "contractor," who undertakes to get and load the coals in the pit, and deliver them to the wharf or place of sale, at so much per ton, the master finding timber, engine, tenter, and loaders into boat. The butty assorts the produce into "coals," "lumps," and "slack," and receives a different price for each description, the highest being that upon the "coals," and the lowest that upon the "slack," which is an inducement for him to obtain as great a proportion of "large" as possible; but there is no corresponding inducement to the men to preserve or increase the proportion of "large." In fact, their great object is to break the large into convenient and handy pieces, the better to enable them to get their day's work sooner done. Generally speaking, the loaders, or bandsmen as they are called, are stinted to so many skip loads for a day's work, irrespective of the class of produce. In cutting the coals, the "pikeman" has no inducement to preserve the better qualities; he has only to get the coals down, no matter to him how, whether in the shape of large coals or slack. Therefore, as there is no inducement for the men, either in cutting or loading, to increase the large coals, the butty keeps an overlooker or "doggy," to see that there is no unnecessary waste in breaking the large

coals to suit the whim of the loader, and this is his only check. This in a great measure would, I think, be obviated in the long wall work, as there the labour test and sub-division of labour can be more readily applied.

In many collieries they raise from twenty-five to thirty-five cwt. per skip load, which, with the height of the skip above the rails on which it is loaded, will be eight feet, so that one-half of the load has to be loaded "overhand," or raised nearly double the height of the operator, which, in my opinion, costs nearly double the amount of labour that it would do, with a differently arranged skip and mode of loading.

Given, A has to lift lumps of coal of one cwt. each, eight feet high, for $(\frac{9}{10\frac{1}{4}})$ $5\frac{1}{4}$ hours (half his time), and B has to lift similar pieces four feet six inches high for the same time. How much more would B lift than A? = 42 : 23,625.

Besides, the grinding effect upon the produce of high loading must be very detrimental as compared with low loading.

The butty, in his contract, finds all tools, skips, horses, corn, candles, and pit beer: in short, everything except the rails and timber.

Besides the butty system, there is what is termed "doggyship," which is carried on by means of a doggy or overlooker, to superintend the operations on "owners' account," the men under him working by the day or stint where practicable.

7.—*Fire Stink.*—"Fire stink," or perhaps more properly termed "spontaneous combustion," or "sulphuretted hydrogen," is nowhere in the kingdom to be found so troublesome as in the thick coal of South Staffordshire, and I am happy to say, it is pretty much confined to that seam. With a seam of such unparalleled thickness, ranging as it does from eight to twelve yards, it cannot become a matter of astonishment that the many and varied thicknesses of the partings, together with the accumulated fine slack and dirt, should form a considerable thickness on the floor of the mine. This, then, is the first cause of all our troubles from this source, and it is quite impossible to entirely remove it. We may mitigate it, and that is all.

In a landsale colliery, where the produce was consumed wholly for household purposes, and no communication with rail or water existed, I have known, after working away the coal, the floor of the workings to be covered, over an area of sixty to eighty acres, with from three to four yards thick of this rubbish, and compelled to be so. What, then, becomes of the cry, that because the coal is of such and such a thickness,

that such and such a produce per acre ought to be made. The produce per acre of this fine seam entirely depends upon the circumstances under which it is wrought.

In the case referred to there is not only the actual loss of at least 4000 tons of otherwise saleable fine slack left underground to the acre, but there is loss of coal in the first working created by the necessity for small sides of work and additional fire ribs. And, further, generally speaking, with such a colliery, in a populated neighbourhood, land could not be got to deposit such rubbish upon, if it were drawn out of the pit; and if it could, the coal owner would at once be indicted for a nuisance, as the refuse once drawn to the surface, immediately, that is, in a few weeks, takes fire from decomposition, the same as if left in the pit.*

8.—*Gases.*—The gases we are most troubled with in the thick coal are sulphuretted hydrogen and carbonic acid, the latter more especially in the second working of the thick coal of what is termed "ribs and pillars." Indeed, so uncertain is the latter, that the horses are required to be drawn up at night if the wind happens to be veering round to the southwest, and whilst in that point, with a corresponding fall in the barometer, it is certain to "put the pit to stand" from choke damp. In working the ribs and pillars great care has to be taken with the air so as not to admit more than is sufficient for the lights and respiration, otherwise the "gob" is kindled into flames in a few days.

Carburetted hydrogen, or what is universally called by the colliers here "sulphur," is rarely of any moment. In new districts, or where it is pent in by faults or dislocations, it is developed, but not in extraordinary quantities. The ordinary test for it is a common Davy-lamp made in the district, with the addition, however, of an extra gauze; the men having great faith in a double, but not in a single gauze. The mode of testing the presence of this gas in a side of work, where the coals are cut down to a great height, is by hooking the lamp by the ring on to a long lamp stick with a hook at the end, and gradually raising the lamp by these means; a second man stands at a distance and watches whether the flame of the lamp changes, and to what extent, and after ascertaining the exact level of the gas, means are taken to remove it before men are allowed to resume their work.

* In practice I have found when the "gob" has commenced to heat, that by digging holes in it and scattering it about, that it would grow cool and not fire again. Having, in the words of the colliers, once "had a sweat," it would not heat or fire a second time, and I have found this invariably the case.

Old Firing Line.—Many years ago, *when less was known of mining, and the times far better,* in order to remove any accumulation of gas from the roof of the mine, the "old firing line" was resorted to, and a candle attached to a string was drawn over a long pole stuck in the loose rubbish on the floor until it came in contact with the gas, by an operator secreted in some safe nook, who was paid a great premium for his foolhardiness; and thus the gas was exploded and got rid of, only, however, to get quit of one nuisance (fire damp) at the cost of producing another (choke damp), at least I apprehend it was so.

Happily, with the introduction of the Davy many years ago, and the constant application of the late James Ryan, who was better known amongst the colliers here by the significant cognomen of "Count Sulphur," ventilation has vastly improved. His great theme was, "remove the cause and the effect ceases," and by adopting his recommendation in this district of driving the air-heading on a level with the roof of the gaitroad, all the gas liberated is immediately carried off by the top air-heading. Previous to this recommendation, which there is not a shadow of a doubt emanated from him (as all his papers and correspondence, left with me at his death, clearly testify), the air-heading was driven universally in the benches, *i.e.*, on the very floor of the mine. In mentioning the name of James Ryan, I must confess the pleasure I felt the other day in perusing a most elaborate and interesting account of this coal-field, by Wm. Mathews, Esq., delivered last year before the Institute of Mechanical Engineers, to find that at least one sterling man could be found therein to do honour to a departed genius, who, unhappily, in his day, was all heart and soul in endeavouring to alleviate the sufferings of the workmen, increasing the wealth of the coal owners, and yet, withal, did so little earthly good for himself or family, for his last moments were comparatively those of a pauper.

9.—*As to the Produce per Acre.*—The almost innumerable circumstances which control and govern the yield per acre, and the proportions of coals, lumps, and slack, is a complete bar to the laying down of any reliable data by which an accurate account of the produce per acre can be obtained. The ton weight of coals in this district is a complete misnomer. There is no such thing. There is a something which is entered in the sales books and paid for as a ton; it is a "parcel," not a ton, but a parcel containing a ton proper, and about one-third of another ton.

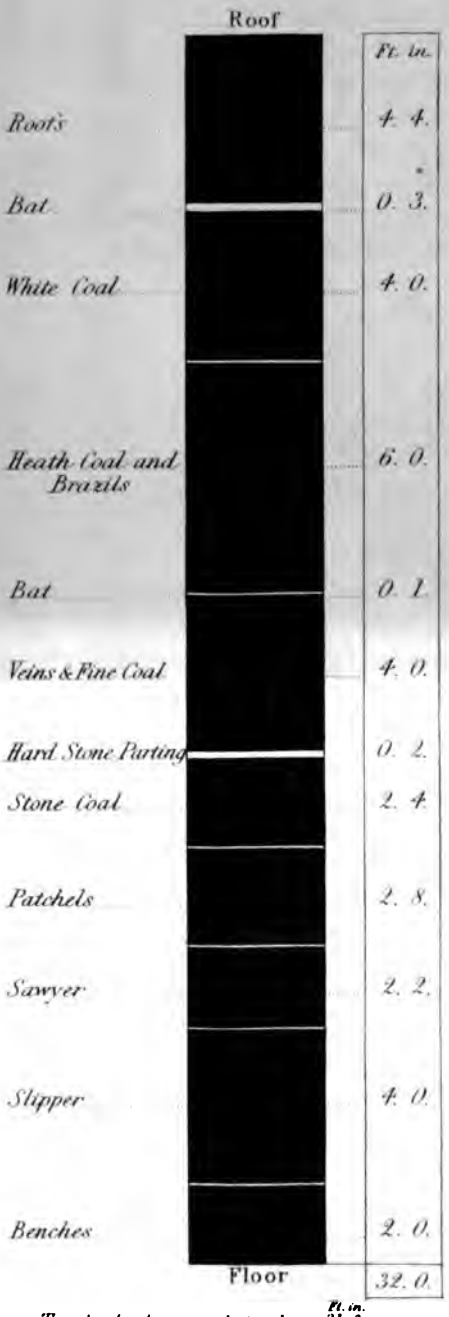
Before estimating the produce per acre of the thick coal of a certain

FIG. 1.

SECTION OF PARK HEAD COLLIERY THICK COAL

Worked by

PILLAR & STALL.



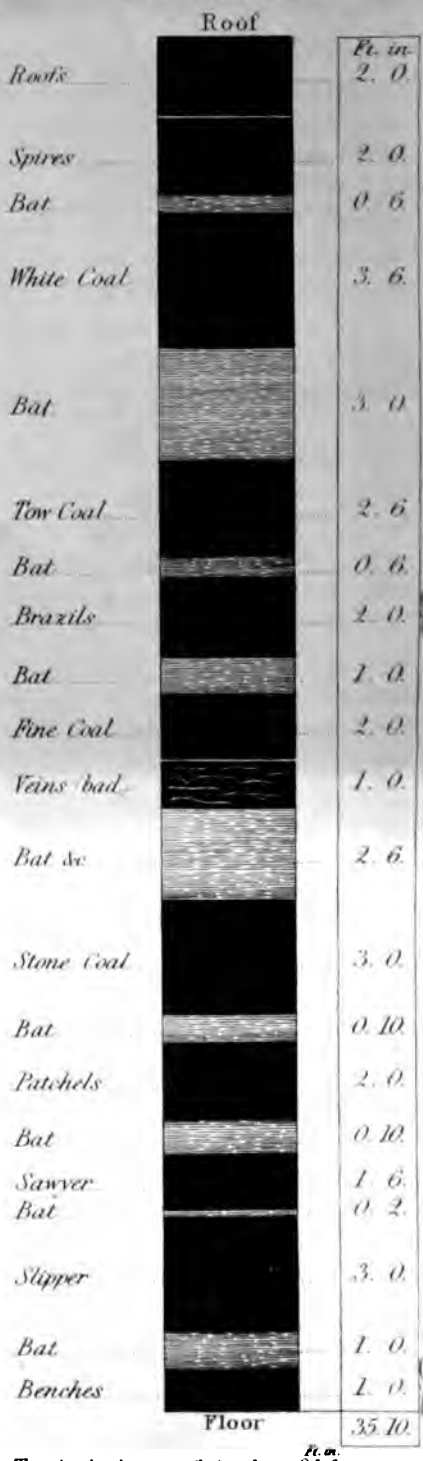
	Ft. in.
Total thickness of Coal	31. 6.
Total thickness of Partings	0. 6.
	32. 0.

FIG. 2.

SECTION OF THE THICK COAL AT HAWN COLLIERY

Which is worked

LONG WALL AT TWICE.



	Ft. in.
Total thickness of Coal	24. 6.
Total thickness of Partings	11. 4.
	35. 10.

Scale 5 Feet to an Inch.

colliery, it will be very necessary to ask some of the following questions, such as:—Is the thickness seven yards or ten yards? Is the mine cut up with faults or dislocations, so as to be more like the hills and valleys of Wales than a deposit of coal, which in many collieries is the case? I can venture no further than to say that the produce of our thick, or ten-yard coal ranges in the first working, from twelve to twenty thousand tons (or rather "parcels") per statute acre, (and I would they were "statute" tons also). In the second working, or "ribs and pillars," the produce would range from 3000 to 7000 tons per acre, according to circumstances.

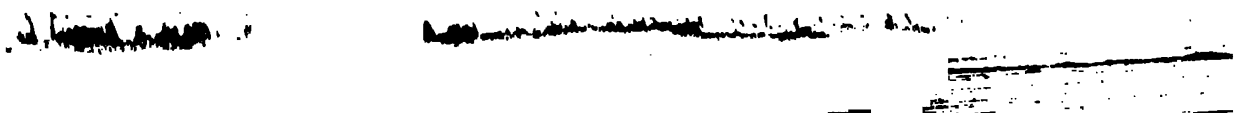
As to the proportions of coals, lumps, and slack, I can give you two extremes from the working in the solid, which came under my notice some time ago. At one colliery of about thirty acres there were—

Coals.....	·43	In another of 80 acres—		Coals.....	·08
Lumps.....	·34	„	„	Lumps.....	·15
Slack.....	·23	„	„	Slack.....	·77
	100				100

The former produced about 19,000 tons to the acre, whilst the latter only produced about 13,000 tons per acre. So that the first-named proportions would be 370 per cent., and the yield per acre of the same would also be 106 per cent. better than the latter.

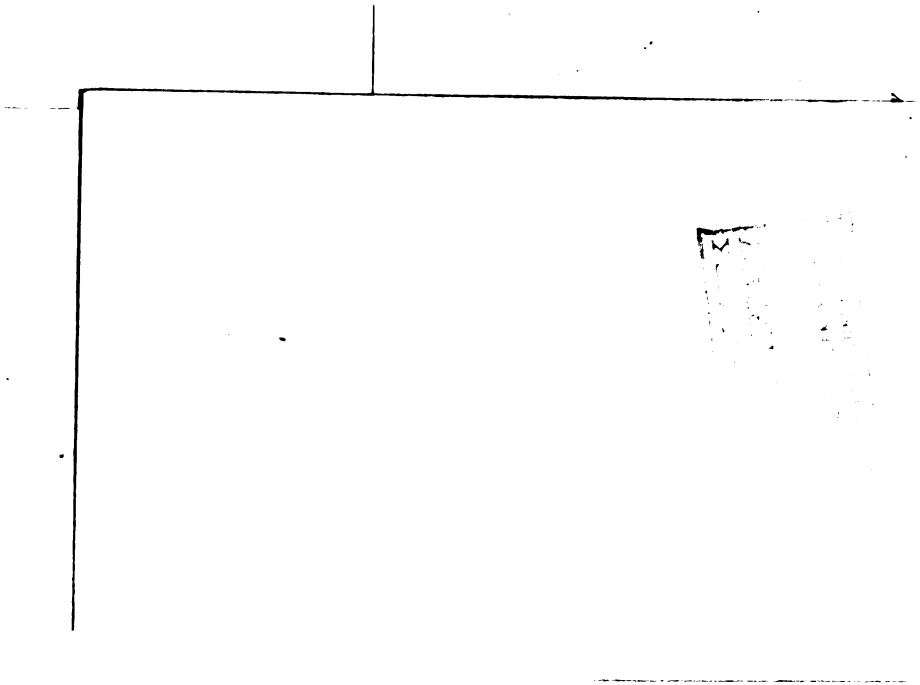
10.—*Park Head Section* (plate III., fig. 1).—The section now before you, and which I will give you a short account of, is from actual measurements, and may, with the greatest truth, be said to be the finest seam of coal in Europe, both for quality, freeness from partings or spoil, and its greater thickness, viz., ten and a half yards of clear coal. But the great misfortune is to have to state it is all gone. Some years ago a very fine section of thick coal was to be seen being wrought "by day," or open work, at Clay Croft, near Foxyards (where the members will visit to-morrow), which was twelve yards and two feet of clear coal, and was said, on good authority, to have produced in the aggregate 40,000 tons per acre. At plate III., fig. 2, is given the section of the thick coal at the Hawn Colliery, near Hales Owen, which shows a thickening of all the partings, separating the several beds composing the great seam, and illustrates the necessity of working it at twice, which is being done by Messrs. Mathews & Co., the owners.

11.—*Faults.*—The thick coal is broken up and its quality much



MECHANICS INSTITUTE
SAN FRANCISCO

MECHANICS' INSTITUTE



ON A

METHOD OF TUBING BORE-HOLES

IN PASSING THROUGH

CLAY, QUICKSANDS, AND OTHER ARENACEOUS AND WATER-BEARING STRATA.

By P. S. REID, Pelton Colliery, Chester-le-Street.

It is a curious fact, that, with the exception of the elementary treatise upon "Well-digging and Boring," published by Mr. Weale, some short time ago, we have no work in the English language which can be properly called a practical treatise upon the science of boring; and in short, unless from the information afforded by what are termed practical mineral borers, it would be most difficult to arrive at a precise knowledge of the present state of the art in this country.

It does not follow from this, that the practical knowledge of this branch of mine engineering is unknown or unappreciated in this country, but simply that whatever is known on the subject by individual engineers, is made available only for their own wants and those of their employers, in that truly practical manner which is the prominent part of an Englishman's self-reliant character, and which places him at once in the first rank in whatever he attempts as a successful initiator.

In France, Germany, and elsewhere, the art of boring, both for artesian wells and for the purpose of proving strata at immense depths, has been elevated into a science or branch of mine engineering, requiring all the skill of the first-rate mechanic, as well as the aid of the analytical chemist, to follow it up; the subject has been thoroughly sifted, and the whole of the different systems of boring described and delineated in their scientific journals and works, commencing from those adopted by the Chinese, and ending with the modern developments given to the science by such men as D'Oeynhausen, Kind, and Dégousée, and embracing all the improvements which have been introduced to the latest date.

It was the writer's intention to have gone into a popular description of all that has come to his knowledge on the subject; but, in the first place, time would not permit him to do it justice, nor get it ready for the present meeting; and, secondly, an elaborate description of the whole of the different systems is capable of being worked up to such an extent, as to form interesting enough matter for several papers, to which some day he expects to be able to return and to introduce them to the Institute, contenting himself, at present, with the best mode of passing quicksands and water-bearing strata, as presented in a boring which he had entrusted to his care in the Cleveland district, and which was intended to prove the formation lying under the lias, and other nonconformable strata, in North Yorkshire.

He need scarcely add to the members, that with the amazing development of coal and iron mines throughout Britain, the proving of strata under these deep deposits, will, before many years, become one of the most interesting questions of the mining engineer, and trusts, a slight reference to the question which will be brought out as he proceeds, will be his excuse for introducing it into the present paper.

The writer was consulted, some years ago, as to the chance of coal being discovered in the Cleveland district, at Kirklevington, near Yarm, and finally was requested to superintend a boring then pursued to the depth of 582½ feet; but which, owing to circumstances which were difficult to determine, had become very expensive, and made slow progress.

The boring had, up to that time, been done entirely by manual labour; the author, therefore, recommended the erection of a horse gin, in which the power was applied to a forty-inch drum placed upon a vertical axle, the arms of which admitted of applying two horses, and men *ad libitum*, the power gained being in the proportion of one to ten at the starting point for the horses.

Upon the upright drum a double-ended chain was attached, which worked over sheer-legs erected immediately over the hole, so as to attain an offtake for the rods of ten fathoms, and so as that, in the act of raising or lowering, there might always be one end of the chain in the bottom, ready to be attached, and expedite the work as much as possible.

These arrangements being made, it was soon found that there was a defect in the tubing which was inserted to the depth of 109 feet, and which was so serious, in permitting the sand to descend and be again brought up with the boring tools, as to render it very difficult to tell in what strata we really were; this increased to such an extent as to cause

the silting up of the hole in a single night to the extent of thirty fathoms, and occupied nearly a fortnight in getting out again.

On carefully examining into this defect, it appeared that the water rose in the hole to the depth of A, fig. 1, seventy-four feet from the surface; and that at this point it was about level with the high water mark on the Tees, about two miles distant, which it was no doubt connected with, by means of permeable gravel beds, extending from the arenaceous strata at B.

On commencing to bore, the motion of the rods in the hole caused the vibration of the water between A and C at the bottom of the tubing, and so disturbed the quiescent sand, as to cause it to run down through the faults in the lower end of the tubing at the latter point.

This tubing was made of galvanized iron plates, similar to that now exhibited, rivetted together and soldered so as to attempt to make it a water-tight casing; at the top of the hole it was in three concentric circles, which had been screwed and forced down successively until an obstacle was met with at each different place shown by the letters D, E, C. So soon as the outer circle* reached the depth of D, all hope appears to have vanished, from those who bored the earlier part of the work, of getting the tube further; a second tube† was, therefore, inserted, which seems to have advanced as far as the point marked E, where it, in its turn, was abandoned; and a third‡ one advanced until it rested in the strata at C, which is, no doubt, the lower part of the lias freestone of a blue nature, as found on the rocks at Seaton Carew, and in the bed of the Leven, near Hutton Rudby.

Such being the account imperfectly gathered from the workmen who superintended the earlier part of the boring, it became necessary to decide upon the best course to remedy the evil. At first sight it would have appeared easy enough to have caught the lower end of the tubes by means of a fish head properly contrived, and thus to have lifted them out of the hole, and replaced them with a perfect tube, such as a gas tube, with faucet screw joints; but, on attempting this, it soon became evident that, however perfect the description of tubing which might have been adopted, it would be a work of the greatest difficulty to extract when once it was regularly fixed and jammed into its place by the tenaceous clayey strata surrounding it; and that the difficulty of extracting, in the present case,

* The diameter of this tubing was 3¼ inches external and 3¼ inches internal.
† This tube was 3½ inches external and 3 inches internal diameter.
‡ This tube was 2¾ inches external and 2½ inches internal diameter.

was even enhanced by the inferior quality and make of the tubing: in short, that unless by crumpling it up in such a manner as to destroy the hole, it was impossible to extract this tubing by main force.

We had, therefore, no other choice left, but to attempt cutting it out, inch by inch; though before doing so, I may add, that we did attempt main force, to the extent of upwards of thirty tons, applied to the bottom of the tubing, in which the only success we attained was, the losing of several pieces of steel down the hole, which we were compelled to fish up with a powerful magnet, such as that now produced, and as these specimens will show.

After much mature consideration and contrivance, it was determined to order such a perfect tubing, as would at the same time present as little obstacle as possible to the clay to be passed through on the outside, as well as surround the largest of the three tubes then in the hole, and present no obstacle to their being withdrawn through its interior.

I ought to add, that in the process of the work, the conviction was forced upon me, that when once the cohesive force of clay like this was fairly gripped and applied on the outside of tubes, passing any great length through it, nothing short of absolute destruction is available to withdraw them.

The tubes, of which fig. 2 shows a section, and the modes of joining them, were made for me by Messrs. G. B. Lloyd, Birmingham, who took extraordinary pains to make them perfect; so much so, as to cause them to say, when their work was completed, that they had had so much trouble to please themselves with them that they felt it was out of their way to make more, but that they must refer me to Messrs. James Russell and Son, of Wednesbury, who had erected machinery better qualified for the work, theirs being chiefly adapted to the finer descriptions of work, such as locomotive tubing, &c.

These tubes were made twelve feet in length, flush outside and in, the lower portion being steeled for six inches from the bottom end, so as to cut its way and follow down the space, and cover that exposed by the old tubes when cut and drawn, as shown at fig. 2.

In order to commence opperations, and avoid too much clay going down to the bottom of the hole, a straw plug was firmly fixed in the lias portion of the hole at F, fig. 1. The lower portion of the new tubes was then screwed on to the top of the old ones by means of powerful clamps, attached to the exterior in such a manner as to avoid injuring the surface, and so soon as it was evident that they could be screwed no further, the

knife or cutter (see figs. 2, 3, and 4) was introduced inside the old tubing. Some force, it will be evident, was needed to get this knife down into the tubing, but the spring *a* giving so as to accommodate itself to the hole, permitted its descent to the distance required; this being effected, it was turned round so as the steel cutter, shown at *b*, being forced against the sides of the tube, cut it through in the course of ten minutes or a quarter of an hour's turning. (See section at *b*, *c*, fig. 4.

The old tubes being (if I may so call it) three-ply, three of these knives or cutters were required to cut out the three tubes, the inner one being detached first, and then the two exterior ones, and so soon as these latter were cut out, as far as they had been forced into the clay, the work became simplified into following down the interior tubing by the new tubes, as shown by the dotted lines from *d* to *e*, until we arrived at the lower end, where it was evident that the old inner tube had been so damaged or torn, either by the putting in or hammering it down, as to leave a vent or fissure for the sand to descend, and thus spoil the whole of the work for all future success in the boring, to say nothing of the very great cost of lifting the sand out, and subsequent most arduous labour to put the hole right.

We finally recommenced the boring after about a month's labour in taking out the old tubings, leaving the new ones firmly bedded into the lias formation, at G, fig. 1, 112 feet from the surface, and subsequently bored to a depth of 710 feet in the new red sandstone formation, proceeding at the rate of about three feet in the twelve hours, and leaving the hole so as, if requisite, it may be widened out to four inches diameter; and, possibly, should more sand be met with on reaching the magnesian limestone, or sands connected with it, it may again be retubed and the work continued to such depth as may be desirable.

I may remark, after saying this much, that if ever an instance could be adduced which merited the designation of "penny-wise and pound foolish," it is the attempt to prosecute so important a work as this boring by means of a so-called water-tight caisson, concocted in so rough a manner by the village tin-man or brazier. I say penny-wise and pound foolish advisedly, because what was meant to be so ultimately turned out the reverse; the new tubes from Messrs. Lloyd actually costing less than the other by about £10, including two journeys to Birmingham and back to explain them and their construction.

To the care of Messrs. G. B. Lloyd in the manufacture I attribute a

good deal of my success in renewing these tubes. At the same time, the experience so gained in their construction convinces me, that if adopted in many places where air-holes are required in mines, and which will not justify the cost of sinking a pit on a large scale by manual labour, good well-made tubes of this description might, even up to eighteen inches diameter, answer as a convenient tubing for air-shaft sides; and the interior could be extracted by boring tools, similarly to the method adopted in artesian wells and mines on the Continent, by Kind and Dégousée.

I am further convinced that in the artesian wells, especially in passing through objectionable springs, the tubes would answer admirably, and that they could, by powerful clamps, be readily forced down, so as to secure a large volume of water from the lower strata, and effectually prevent the injurious mixture of inferior supplies.

Fig. 1 shows the geological position of the upper portion of the bore-hole, and the depth to which the imperfect tubing was inserted; it also shows the tidal range, which we were ultimately able to take advantage of, by sinking so as to get four fathoms more offtake, and expedite the work; the water still rising only to A, and flowing away from that point when passed down the hole. Fig. 2 shows the action of the knife and spring cutter, when forced down into the tubing, ready to commence cutting. It also shows the lower end of the new tubing enclosing the others at the commencement of the work, the junction of the tubes, by means of the half-lap screw, being shown at *j*. Fig. 3 shows a front view, with knife or cutter, *b*. Fig. 4 shows the action of the spring and cutter when the requisite length is cut through and ready for lifting; the position of the tube being maintained perpendicular, or nearly so, by the ball or thickening on the rods at *k*, and the lower end of the tube being supported by the projecting steel cutter at *b*. The dotted lines from *d* to *e* showing the position of the new steel-ended tube when screwed down ready for another operation. In boring deeper after the tubes were removed, three wooden blocks were used round the rods in the new tube to keep them plumb.

In examining the nature of the strata thus passed through, as described, it will be evident, that to ensure success, the tubing, of whatever it is made, should be as truly cylindrical as possible, straight, and flush surface, both outside and in. It will also be evident that in thus joining pieces of tubing together in this manner, the thickness ought to have a due proportion to the work required, and the force likely to be used in

screwing them down; and, also, that the only correct way of getting such tubes effectively into the ground is by screwing and not hammering, as in the case of pile-driving, or similarly to forcing a nail in. The author has seen this attempted on several occasions, but invariably with failure to the success of the work, and is convinced that no successful practical borer will adopt such measures.

In some cases it has come to the writer's lot to widen out holes below the sharp edge of tubing, so as to permit its descent. This is an operation requiring great care and attention, and may hereafter be noticed; but, in conclusion, he would observe that no branch of mine-engineering is qualified to bring out more thoroughly the abilities of a young engineer, than a perfect knowledge of the science of boring, requiring, as it does, the best mechanical skill, as well as the best knowledge of assaying rocks by chemical analysis. He is aware of more than one deep boring in important districts, which were finished many years ago, and cost large sums of money, but which, in the then knowledge of chemistry, were not critically examined, and hence, so far as their results are concerned, are utterly useless; the fact being, that beyond the colour of the material bored through, it is unknown whether it was a limestone, or what it was, to this day.

A vote of thanks was then given to Mr. Reid for his paper, and it was arranged that the discussion thereon should be taken with that of the other papers when the proceedings were printed.

ON THE VARIOUS MODES OF ASCERTAINING

THE VELOCITIES OF CURRENTS OF AIR IN MINES,

IN ORDER TO DETERMINE THE QUANTITIES CIRCULATING IN A GIVEN TIME.

By JOHN J. ATKINSON and JOHN DAGLISH.

In the ventilation of mines, great advantages are well known to arise from dividing the air into a series of currents or splits, and its proper distribution amongst these is an object of very great importance, because, upon it depends, to a certain extent, not only the actual amount of the gross quantity that will be put into circulation, in a given time, by any ventilating power that may be employed, but also the relative degrees of safety and salubrity that will prevail in the different districts into which the mine is divided.

In order to effect this distribution of the air in such a manner as to obtain the most efficient general ventilation, and, at the same time, to allot to each district or split its proper share or proportion of the whole, it is essential to have some satisfactory mode of ascertaining the velocities of the currents, and the quantities of air circulating in each of the splits in the unit of time.

The various methods that have been employed for this purpose may be divided into three groups.

First.—By travelling at the same velocity as the current, and noting the distance passed over in a unit of time.

Second.—Determining, from observation, the rate at which small floating particles are carried along by the current, and assuming their velocities to be identical with that of the air current itself. Smoke from exploded gunpowder, burning turpentine or amadou, small pieces of down, and small balloons filled with hydrogen, have been all more or less employed for this purpose.

Third.—By using anemometers, or apparatus of various forms; and these may be divided into three classes:—(a) Anemometers having vanes or wands, made to *revolve* by the current of air impinging upon them, the rate at which they revolve being indicated by pointers on dials forming a part of the instrument—the pointers being made to revolve by means of wheels connecting them with the axis of the vanes or wands. The anemometers of Combes, Biram, Whewel, Osler, and Robinson, are instances of this class of instruments now in use in this country, all of which require a correction for friction. (b) Instruments which are affected by the *force* or impulse of the wind, without being subjected to any continuous revolving motion, such as Dr. Lind's, Henaut's, Bougier's, and Dickinson's anemometers. (c) Anemometers of a more complex character, such as Leslie's.

First group.—Perhaps the primitive mode of ascertaining the velocity of currents of air in mines, was that of choosing a part of the gallery forming the air-way, having as uniform sectional dimensions as could be found, and after measuring off a distance of 100 to 150 yards in length, taking a lighted candle and walking in the direction of the current, holding the flame in such a position as to be fully exposed to the influence of the current, but taking care to walk at the particular rate required, to cause the flame to burn in an upright position, without being deflected from the vertical, either by the current or by the progress of the person carrying it. The time required to traverse the distance measured off, being noted by a seconds watch, enabled the average rate of walking to be determined; and the average rate so found, from three or four trials, was assumed to be the velocity of the air-current; and this, multiplied by the average sectional area of the part of the air-way selected for the experiment, was taken to represent the quantity of air passing in the unit of time. Formerly, when this mode of measuring the air in mines was in use, it would afford a close approximation to the truth; but, with the ventilation now existing in many of our large mines, it would not be practicable to walk as quickly as the currents travel in the principal splits; and running is not a sufficiently steady pace. One of the objections to this, as well as to all other methods that require a considerable distance to be traversed, over which to observe the velocity, is the difficulty of obtaining a gallery of equal area throughout, over a sufficient distance; but in cases where this is attainable, this method admits of great accuracy for velocities up to 400 feet per minute; in fact, the writers have been able to obtain as accurate results by this method as

by any other; as can be seen by referring to No. I. *Diagram and Table of Experiments.** In this and the other diagrams, the coloured lines are obtained by taking the *actual* velocities of the air-currents (ascertained as hereafter described), and the revolutions of the anemometer, or other *indicated* velocities, as coördinates. If the indicated velocity were the same as the actual velocity, a line drawn through the points where they would intersect each other in the diagrams, would exactly coincide with the simple straight diagonal; but as the one exceeds the other, so the coloured lines drawn through their points of intersection depart more or less from the diagonal. The *black* line, partially dotted to avoid confusion with the yellow, in this diagram, is formed by taking, as coördinates, the velocities obtained by walking with a lighted candle, and the true velocities, which in this case were found by correcting the readings of a Biram's anemometer, in the manner afterwards described at page 216.

The close approximation of this line to the diagonal, shows that great accuracy can be attained by this method. It ought, however, to be mentioned, that the place where the experiments were made, was in all respects suitable, and specially adapted for the purpose, being perfectly level, and of an accurately uniform sectional area throughout the whole distance of 200 feet.

Second group.—One of the principal of the second group of modes employed for the measurement of air, consists in observing the velocity of the smoke from an exploded charge of gunpowder in a part of the gallery, of nearly uniform sectional area; and this, until recently, was the means most generally adopted in the coal mines of this country, for ascertaining the velocity of air-currents; and although it has of late been largely superseded by the use of Biram's anemometer, the practice is still in considerable use, and, so far as regards shaft velocities, remains the only method. It is, therefore, desirable to ascertain how far the results obtained by this, and similar methods of measuring air-currents, can be relied upon for accuracy; and to investigate the various sources of error connected with them, with a view of either avoiding or making proper allowances for their effects, so far as may be practicable.

The sudden explosion of gunpowder in the confined passages of mines produces several effects, which tend to cause inaccuracies in the results obtained by noting the passage of the smoke, as an index of the velocity of the current.

* No. III. diagram has been constructed specially to exhibit the mode of arriving at the formula.

Experiments prove (as, indeed, might have been anticipated, considering the small quantities of gunpowder used), that in general neither the increase of bulk due to the introduction into the current of the *products of combustion*, nor that due to the *elevation of temperature*, have any appreciable effect on its velocity. But other experiments show that the *force of the explosion*, when a considerable quantity of gunpowder is used in a feeble current, gives an impulse to the current, and creates a velocity in excess of the normal one. A revolving anemometer was placed in an air-passage traversed by a feeble current, so regulated as to be just strong enough to produce thirty revolutions of the instrument per minute. The explosion of a cubic inch of gunpowder, at a distance of seventy feet, did not in any way affect the instrument; but when the charge of gunpowder was increased to twenty cubic inches, the explosion caused a sudden and violent increase of its rate of revolving, acting as a temporary impulse, the revolutions very quickly decreasing to the original number again. The same effect is also clearly shown in the second series of experiments, page 211. The amount of error arising from this source, and which tends to *increase* the apparent velocity, depends on the quantity of gunpowder used, the sectional area of the air-way, and the velocity of the current, increasing with the quantity of gunpowder employed, but decreasing as the sectional area of the air-way and the velocity of the current are increased, so that the explosion of a large quantity of gunpowder in a feeble current of air passing over a short distance in a gallery of small sectional area, will be attended with the greatest errors; but as, under the ordinary conditions of the currents and air-ways of mines, one cubic inch of gunpowder does not give rise to any sensible error from the cause alluded to, and as it affords sufficient smoke to be readily observable at a distance of 200 feet, that quantity has been adopted as a standard, and used in the experiments made by the writers.

It appears to be very desirable that a standard quantity of gunpowder should be employed in all cases, whether in the ordinary measurement of air or in conducting experiments, to enable comparisons to be made, as any variation in this respect will give rise to discrepant results.

If a charge of gunpowder be exploded in an air-current, and the velocity of its smoke be timed over a series of consecutive and equal distances in an uniform air-way, it will be found to be apparently most rapid near the point of ignition, and to decrease gradually as it flies to a greater distance from that point. This is a most serious source of error, and may be regarded as fatal to the accuracy of this method of determining the velocity of a current of air. It probably results from the *diffusion, con-*

densation, and deposition of the smoke arising from the explosion, and tends to *decrease* the apparent velocity.

The following experiments, selected from many others giving similar results, will show this.

The charge in each of these experiments was one cubic inch of gunpowder, which was exploded ten feet to the windward of the commencement of the first space, or interval of twenty-five feet, and the time was noted when the smoke reached the commencement and also the end of each of the two intervals of twenty-five feet, into which the total distance of fifty feet was divided.

EQUAL QUANTITIES OF GUNPOWDER AT DIFFERENT VELOCITIES.

Time in passing over first interval of twenty-five feet.	Time in passing over second interval of twenty-five feet.	Total time.	Average velocity of the air-current, as indicated by the smoke.
15″ ..	21″ ..	36″ ..	83 feet per minute.
12½″ ..	15½″ ..	28″ ..	107 „
6½″ ..	9″ ..	15½″ ..	193 „
5″ ..	5½″ ..	10½″ ..	285 „

In the above experiment it will be noticed that in all cases the time occupied in passing over the second interval is greater than that occupied in passing over the first; and it is further observable that this difference decreases as the velocity of the air increases. At the low velocity of 83 feet per minute the times are 15″ and 21″, being a difference of 40 per cent. of the lesser time; whilst at the higher velocity of 285 feet per minute, the difference between 5″ and 5½″ only amounts to 10 per cent.

The charge of gunpowder, in the two following series of experiments, was varied in quantity, and exploded 20 feet to the windward of the first interval; the time being noted, as before, when the smoke reached the commencement and also the end of each of the two intervals of 50 feet.

First Series.

DIFFERENT QUANTITIES OF GUNPOWDER AND EQUAL VELOCITIES.

Quantity of gunpowder. Cubic inches.	Time in passing over first interval of 50 feet.	Time in passing over second interval of 50 feet.	Total time.	Average velocity of air current, as indicated by the smoke, in feet per minute (presumed average).
1 ..	37″ ..	45″ ..	82″ ..	75
4 ..	27″ ..	35″ ..	62″ ..	„
20 ..	15″ ..	24″ ..	39″ ..	„

Second Series.

1 ..	5″ ..	5″ ..	10″ ..	600
4 ..	5″ ..	5″ ..	10″ ..	„
20 ..	4″ ..	5″ ..	9½″ ..	„

It will be observed in these experiments—1st. That in a slow current

(seventy-five feet per minute), with twenty cubic inches of gunpowder, the time occupied by the smoke in passing over the second interval of 50 feet, was sixty per cent. more than it occupied in passing over the first interval of 50 feet, showing that the *apparent* velocity gradually decreased. These experiments further show, that this gradual loss of velocity is greatest where the charge of powder employed is greatest. 2nd. That the apparent velocity, and, therefore, the apparent quantity of air, is more than doubled (being in the proportion of eighty-two to thirty-nine) with the low velocity, by using twenty cubic inches of gunpowder instead of one inch. 3rd. That these discrepancies are by far the greatest at low velocities, and are hardly apparent at high velocities, as will be seen by the *second series.*

The smoke resulting from the explosion of gunpowder is not of the same density as the air-current. This has been observed by previous experimentists, and has been confirmed by the writers by substituting turpentine smoke, which can be observed at a distance of 50 feet, but which dissipates, and cannot be accurately observed at 100 feet.

1 cubic inch Gunpowder.					Turpentine.				
1st Interval, of 25ft.		2nd Interval, of 25ft.		Total.	1st Interval, of 25ft.		2nd Interval, of 25ft.		Total.
17	+	21	=	38	11	+	14	=	25
13½	+	16½	=	30	10	+	12	=	22
7	+	9	=	16	8	+	8	=	16

It will be noticed, that whilst gunpowder smoke required 38″, 30″, and 16″ respectively, to travel a distance of 50 feet; in a current having the same velocity turpentine smoke required only 25″, 22″, and 16″. But it may be observed, that experiments made with turpentine smoke are very unsatisfactory. The turpentine cannot, like gunpowder, be ignited in a large quantity simultaneously, but resembles more the ignition of a train of gunpowder; added to this, the resulting smoke is very difficult to discern, and is soon dissipated. Other writers mention experiments made with Amadou smoke, Down, and Balloons, but from experiments made with the greatest care, and under the most favourable circumstances, with each of these, by the writers, they conclude that such previous experiments could only have given totally erroneous results, as these substances do not appear to them to be at all adapted to give true velocities.

Experimentists, who have written on this subject, have also noticed another source of error in all currents, especially in the more feeble, in the eddies and streams of varying velocity which almost always exist; and when any small particles or light bodies are introduced into the currents, a part of them get into the axis of greatest velocity, and give

a result higher than the average; other portions fly too slow; and even on the average of the first and last particles traversing the distance, the results are too low.

Similar remarks are applicable to the use of smoke; at least Mons. Jochams (Vol. IX. Annales des Travaux Publics de Belgique) came to these conclusions on comparing the results of his experiments by these modes with the corresponding and simultaneous observations made with Combes' anemometer. The results of his experiments, indicating the distances traversed per second, by the different agents, are given in the following tables.

	Velocities deduced from Mons. Combes' Anemometer.	Velocities of the Current of air observed with				Down.
		Powder Smoke.		Amadou Smoke.		
		First of Smoke.	Average of Smoke.	First of Smoke.	Average of Smoke.	
Metres.	4·84	....	....	....	....	4·31
,,	1·53	1·67	1·25	1·56	1·19	
,,	2·34	2·78	2·00	2·50	2 00	

In reference to the down especially, if it got out of the axis of the air-way where the most rapid current prevailed, it adhered to the damp walls of the gallery, and was, consequently, greatly retarded.

The various sources of error connected with the use of gunpowder smoke, are given in the following tabular form :—

CAUSES OF ERROR IN EXPERIMENTING ON THE VELOCITY OF AIR-CURRENTS IN MINES, BY MEANS OF GUNPOWDER SMOKE.

CAUSE.	EFFECT.
1.—The expansion of the whole column of air, by the addition to it of the results of the combustion of gunpowder, and by the heat developed (*of slight magnitude*).	Tending to *increase* apparent velocity, owing to two causes, viz. :— 1.—The conversion of a small portion of solid gunpowder into gas. 2.—The further expansion of this, owing to the high temperature of ignition.
2.—The explosive force of gunpowder (*of considerable magnitude*).	Tending to *increase* the apparent velocity, and can be avoided with care.
3.—Diffusion or deposition of the smoke.	Tending to *decrease* very considerably the apparent velocity.
4.—Eddies and currents. 5.—The density of the smoke.	Giving rise to serious irregularities, materially affecting the accuracy of the results.

PRECAUTIONS TO BE USED IN EXPERIMENTING WITH GUNPOWDER SMOKE.

By the use of fixed quantities and distances, and the avoidance of extreme velocities,

The following *Table of Experiments*, made by timing gunpowder smoke, by walking so as to keep the flame of an exposed light in a vertical position, and by the use of a Biram's anemometer respectively, is given with a view of showing the comparative degrees of accuracy of these different modes of measuring currents of air; and the results are graphically exhibited in *Diagram No. I.*

TABLE No. 1.

Experiments made with Gunpowder Smoke, Walking, and an Anemometer (Biram's 6-inch), in the same Current of Air.

	Gunpowder Smoke.			Walking.	Anemometer.	
	Equal distances.		Equal times.		Recorded revolutions. = R.	True velocities calculated. $v = \cdot 97\ R + 40$, nearly.
	50 feet.	200 feet.	20 sec.	200 feet.		
	Blue.	Yellow.	Red.	Black, partially dotted.		
	Feet per minute.	Feet per minute.	Feet per minute.	Feet per minute.	Revolutions.	Feet per minute.
1	125	100	..	88	44	83
2	158	162	..	..	90	127
3	166	..	171	162	103	140
4	250	214	228	..	188	222
5	285	..	..	..	220	253
6	300	255	263	255	233	266
7	353	307	307	307	293	324
8	461	413	428	413	407	435
9	545	500	502	500	482	507

Explanation of Table No. I., and Diagram No. I.

No. 1 *Column* (blue line).—In those experiments the time during which the powder smoke travelled a distance of 50 feet was observed,

---

an *approximation* to accuracy in the measurement of air-currents by gunpowder smoke may be attained; and the numerous experiments made by the writers suggest the following precautions as being necessary :—

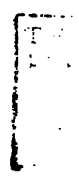
First.—Always to use one cubic inch of gunpowder as a standard.

Second.—The *velocity* of the current never to be less than 100 feet per minute, nor to exceed 500 feet per minute. In order to attain this, a gallery of such area must be selected as will afford this velocity of current.

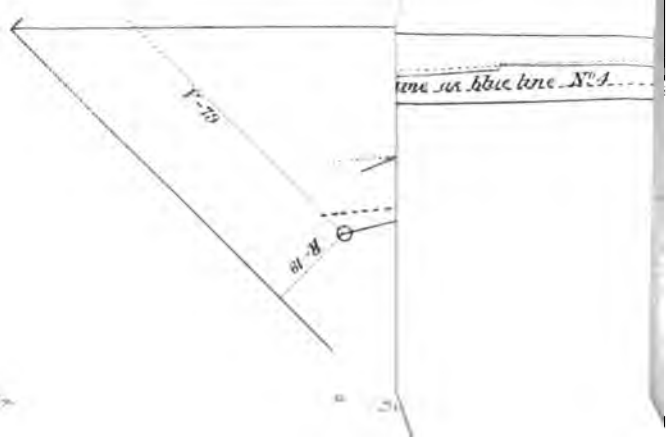
Third.—The *time* not to be less than twelve seconds, nor to exceed thirty seconds.

Fourth.—To explode the gunpowder ten feet to the windward of the first mark.

Therefore, in slow currents of from 100 to 250 feet per minute velocity, the distance to be taken over which the smoke passes will be fifty feet; and for the higher velocities of from 250 to 500 feet, the distance will be increased to 100 feet.



THE NEW YORK
PUBLIC LIBRARY
ASTOR, LENOX AND
TILDEN FOUNDATIONS



om it the velocity per minute calculated; thus, in the first experi-
he time so occupied was 24″, indicating a velocity of 125 feet per
, this is the ordinary mode of finding the velocity of air by powder

ill be observed, that owing to the distance travelled over by the
being short, the velocities of the smoke are in excess of the true
ies of the air.

No. 2 *Column* (yellow line), the distance over which the time of
wder smoke is noted is 200 feet instead of 50 feet; and, it will
erved that the apparent velocities here are less than the true ones,
ing in the two first experiments, where the contrary result is due
bly to the explosive force of the gunpowder in a feeble current.

. 3 *Column* (red line)—Experiments made by using "equal times,"
d of "equal distances," and varying the distance, so that in each
riment the *time of observation* was as nearly as possible the same.

o. 4 *Column* (black line dotted to avoid confusion with the yellow).—
eriments made by walking 200 feet with a lighted candle, and noting
ime, and calculating velocity per minute therefrom.

o. 5 *Column.*—Velocity as recorded on the dial of a Biram's anemo-
r, the same as the blue line in *Diagram III.*, and explained at page

These readings require correction by the formula (for this instru-
t nearly) V = ·97 R + 40,

where V = the velocity of the air-current in feet per minute;
and R = the revolutions of the anemometer, as shown by the
index on its dial, in the same time.

e corrected readings are given in *column* 6, and are taken as the
dard or *true velocities.*

ese experiments were conducted with the greatest care, in a gallery
mine specially adapted for the purpose, by being made perfectly
, and of uniform sectional area; during the experiments the velo-
was kept as constant as practicable throughout, by keeping the water
e of that part of the mine at a uniform height. The observations
taken with a large seconds watch, specially adapted to this purpose,
all experiments were repeated until a correct average could be
ined; but even under these circumstances, which in general will not
ail for ordinary measurements in mines, great discrepancies are obser-
e between the results obtained by timing smoke over equal distances,
those obtained either by timing smoke during equal times, or over
l distances of different lengths. Doubtless, such an empirical rule

could be found, for so regulating the distance to be traversed, the amount of powder to be exploded, and the duration of the experiments, as that with great care nearly accurate results could be obtained; still the difficulty of obtaining galleries fully adapted for the purpose, by their uniformity of sectional area, &c., and the numerous chances of error in observation are so great, that it is most desirable that there should be some more ready and accurate mode of ascertaining the velocities of currents of air; anemometers of various constructions have of late been more or less employed for the purpose, and it is therefore, important to ascertain how far the indications of such instruments can be relied upon for accuracy.

REVOLVING ANEMOMETERS.

The anemometer most generally used in the coal mines of England is that introduced by the late Mr. Biram, and as its construction is doubtless known to all the members of the Institute, it will not be necessary to give more than a general description of the nature of the instrument, the more so as it is minutely described in the evidence of the late Mr. Biram before the Parliamentary Committee on Accidents in Mines, 1849, page 179. It consists of a series of vanes, which revolve with the action of the air-current—the number of revolutions, or, rather, numbers proportional to the revolutions, being registered by pointers on the face of a dial forming a part of the instrument itself. It is made of three sizes, 4, 6, and 12 inches; is very portable; and is not, with proper care, liable to get out of order, especially the smaller size. A certain force of current is required to overcome the friction, and put the instrument into motion. Some of these instruments will continue to revolve in a current as low as 30 feet per minute, but with the most of them a velocity of about 50 feet is required. Every one who has occasion to use this anemometer should be aware that it does not register the actual velocity of the air, especially in feeble air-currents; nor yet the number of revolutions of the wands, but only a number proportional to the latter; and although it is of great value, as indicating an increase or decrease in the velocity from time to time, such as the periodical variations in any particular current, it is of comparatively little value, *as generally used*, for ascertaining real velocities, such, for instance, as occur in changing or splitting air-currents, when it is of great importance to know the actual quantities. To obtain, with this instrument, accurate results, available for all purposes, it is necessary, as with Combes' anemometer, to apply a formula to its

THE NEW YORK
PUBLIC LIBRARY
ASTOR, LENOX AND
TILDEN FOUNDATIONS

ecorded revolutions, or, rather, to the number indicated by the index, n order to ascertain the actual velocity of any current; each particular nstrument requiring special experiments to be made with it, in order to Letermine the value of the constants required to be employed in the ormula. These constants, however, remain the same for the same nstrument, so long as it remains in the same condition, and are indeendent of the velocities of the currents of air in which it is employed.

To obtain the constants of this formula, as applicable to any particular nstrument, it is absolutely necessary, in making the experiments, to now correctly the true velocity, as a standard of comparison. As before xplained, none of the ordinary modes employed for ascertaining the real elocities are reliable; the writers, therefore, had a Whirling Machine onstructed, the wand of which, in revolving, described a circle of 25 feet in circumference; the number of its revolutions being indicated by a pointer on a dial.

In the first instance, this Whirling Machine was turned by the hand, ut as this did not give a sufficiently uniform velocity, a small drum, and rope with a descending weight attached to it, was employed, to give notion to the machine; and worked thus it gave extremely accurate esults; so far, at least, as regards the uniformity of its own velocity. By fixing the anemometer on the end of the wand, the velocity with vhich it passes through the air can be ascertained and compared with he revolutions of the anemometer, as indicated on its dial. *Drawing No. II.* represents this machine.

It has been stated by some writers that there is a difference between he force or impulse of air moving upon a body at rest, and the resistance vhich a body moving through a still atmosphere meets with in its pasage, supposing the velocity to be the same in each case; and besides his, the effect of a body moving in a circle, in a still atmosphere, may ot be the same as when moving in a straight line. The experiments of Hutton and others appear, however, to indicate that the force of impact f a wind against a stationary body is always proportional to the resistnce which a solid, moved through a still atmosphere, meets with at the ame velocity.

COMPARISON OF GOVERNORS.

No. III. Diagram.

The following experiments were made with the Whirling Machine, nd the results are given both in a diagram and in a tabulated form.

iagram the different coloured lines are drawn through the
ou by taking the actual velocities of the anemometer through a
till atmosphere, and the numbers indicated by the pointers of the
nometer as being passed over in the unit of time, as the coördinates
of a line or curve in each series of experiments made at different velo-
s under the same conditions, and with the same anemometer.

) anemometers at the commencement of the experiments were made
revolve by the Whirling Machine in a circle only 10 feet in circum-
nce; but as the rate of revolution appeared to be somewhat irregular,
nat board, intended to regulate the motion and render it uniform, was
ed at the end of the revolvi d opposite to that at which the
anemometer was fixed, and the ments shown by the *red* and *yellow*
lines were made, the former w regulating board projecting down-
wards, and the latter with it ing upwards, from the revolving
wand.

The discrepancies betwee es are so slight that the mere
position of the regulating bc aot appear to have any sensible
effect; the changes in the abration of the anemometer, and
errors of observation, being account for the slight differences
that exist.

The *blue* line in the same hibits the results of certain expe-
riments made with the same anemometer in the same sized circle, but
without any flat board or governor on the wand; and as these experiments
give results differing considerably from the two lines obtained with the
governor on the wand, we infer that the governor really produces some
effect.

As, however, all the three lines are sensibly straight, the inference is that the effect does not arise from any greater uniformity in the rate of motion with, than exists without, the board; because so long as the lines are straight, it follows that an average speed, however irregular, would, on the whole, give the same general results as a uniform speed equal to such average; and hence we infer that the governor only produces an effect that is disadvantageous, arising probably from disturbing the stillness of the atmosphere in which the experiments are conducted. On these considerations we are led to reject the experiments made with the governors, and, so far, adopt those shown by the *blue* line in which no governor was used.

This view was partly confirmed on using a longer wand and causing the anemometers to revolve in a circle 25 feet in circumference,

in lieu of one of only 10 feet in circumference; as, under these circumstances, the irregularity of the rate of revolution is much less apparent.

The results of the experiments give a straight line in the diagram, and lead to a formula of the form of $V = m R + a$, the same as arrived at by Mons. Combes, where

V = velocity of air;

R = revolutions of anemometer; or rather, the numbers indicated by its index, in the unit of time;

And m and a each constants, suited to the friction of the anemometer, the form of the vanes, and the density of the air.

The experiments represented by the *blue* line in the diagram are fairly represented by the formula $V = \cdot 9685\ R + 40\cdot 5$.

The rejected *red* line in this diagram represents experiments made with an anemometer revolving in a horizontal circle 25 feet in circumference, through a still atmosphere, with a governor-board 2 feet in area fixed upwards, at the contrary end of the wand to that on which the anemometer was fixed, and give rise to a similar formula, namely, $V = \cdot 9197\ R + 40\cdot 5$.

While the rejected *yellow* line represents experiments made under similar conditions with the same anemometer, excepting that the governor in this case was turned downward, and give $V = \cdot 9\ R + 45\cdot 3$; so that on the whole the use of the governor appears to increase the numbers indicated by the index of the anemometer, excepting, perhaps, at very low velocities.

No. 3 Table of Experiments, made with a 6-inch Biram's Anemometer, to ascertain the effect of placing a board on the end of the wand of the Whirling Machine, to act as a governor; the circle described by the wand being 25 feet in circumference.

No. of Experiment.	Without the Governor or Board. Blue Line (same as Red of No. 4).					Board Upwards. Red Line.					Board Downwards. Yellow Line (same as Red of No. 6).				
	Velocity.			Error.		Velocity.			Error.		Velocity.			Error.	
	Number indicated by Index of Anemometer = R.	Actual Velocity = V.	Velocity calculated by formula V = 9668 R + 40·8.	More.	Less.	Number indicated by Index of Anemometer = R.	Actual Velocity = V.	Velocity calculated by Index of Anemometer V = 9197 R + 40·8.	More.	Less.	Number indicated by Index of Anemometer = R.	Actual velocity = V.	Velocity calculated by formula V = 9 R + 40·8.	More.	Less.
1	25	67	..	..	..	43	85	..	..	..	56	99	..	..	..
2	42	81	81	..	..	49	89	..	..	..	65	104	..	..	..
3	96	133	..	..	..	50	89	..	..	..	71	108	109	1	..
4	97	133	..	..	..	53	92	..	..	..	72	113	..	..	..
5	98	133	..	..	..	53	92	..	..	..	72	112	..	..	..
6	104	141	..	..	..	95	129	..	..	..	75	106	..	..	..
7	120	158	157	..	1	97	131	..	..	..	75	106	..	..	..
8	126	164	..	..	..	97	131	130	..	1	107	142	..	..	..
9	142	175	..	..	..	98	131	..	..	..	107	142	..	..	..
10	149	183	..	..	..	98	133	..	..	..	107	142	..	..	..
11	173	205	208	3	..	127	156	..	..	..	108	142	142	..	..
12	175	207	..	..	..	128	156	..	..	..	150	180	..	..	..
13	214	250	..	..	..	131	158	160	2	..	152	181	..	..	..
14	223	258	..	..	..	132	158	..	..	..	153	183	..	..	..
15	233	267	..	..	..	137	168	..	..	..	153	183	..	..	..
16	242	272	..	..	..	137	168	167	..	1	195	225	..	..	..
17	270	300	..	..	..	137	168	..	..	..	196	223	..	..	..
18	293	325	..	..	..	140	171	..	..	..	198	225	..	..	..
19	302	333	333	..	..	140	171	..	..	..	198	225	225	..	..
20	..	..	..	..	..	141	172	..	..	..	199	225	..	..	..
21	..	..	..	..	..	158	183	..	..	..	223	248	..	..	..
22	..	..	..	..	..	208	233	..	..	..	223	248	..	..	..
23	..	..	..	..	..	210	233	..	..	..	252	267	..	..	..
24	..	..	..	..	..	211	235	..	..	..	253	273	..	..	..
25	..	..	..	..	..	211	235	..	..	..	256	273	275	2	..
26	..	..	..	..	..	236	260	..	..	..	..	..	..	..	..
27	..	..	..	..	..	237	258	..	..	..	..	..	..	..	..
28	..	..	..	..	..	238	260	..	..	..	..	..	..	..	..
29	..	..	..	..	..	238	260	..	..	..	..	..	..	..	..
30	..	..	..	..	..	239	260	..	..	..	..	..	..	..	..
31	..	..	..	..	..	240	260	..	..	..	..	..	..	..	..
32	..	..	..	..	..	242	264	..	..	..	..	..	..	..	..
33	..	..	..	..	..	249	267	..	..	..	..	..	..	..	..
34	..	..	..	..	..	250	269	..	..	..	..	..	..	..	..
35	..	..	..	..	..	252	271	..	..	..	..	..	..	..	..
36	..	..	..	..	..	256	275	..	..	..	..	..	..	..	..
37	..	..	..	..	..	270	287	..	..	..	..	..	..	..	..
38	..	..	..	..	..	313	333	..	..	..	..	..	..	..	..
39	..	..	..	..	..	317	333	..	..	..	..	..	..	..	..
40	..	..	..	..	..	317	329	..	..	..	..	..	..	..	..
41	..	..	..	..	..	319	333	..	..	..	..	..	..	..	..
42	..	..	..	..	..	320	333	..	..	..	..	..	..	..	..
43	..	..	..	..	..	345	358	..	..	..	..	..	..	..	..
44	..	..	..	..	..	355	367	..	..	..	..	..	..	..	..
45	..	..	..	..	..	355	367	367	..	..	..	..	..	..	..

NOTE.—In these tables only a portion of the velocities have been calculated out.

COMPARISON OF ANEMOMETERS.

No. IV. Diagram

Exhibits graphically the results of experiments made with three Biram's anemometers of the different sizes, on the Whirling Machine, in a circle of 25 feet in circumference, without any governor. We observe, that for the 4-inch and 6-inch anemometers, the lines are sensibly straight, and the formula consequently simple, and of the form previously indicated. With the 12-inch anemometer, however, the line is curved, and the formula complicated, and troublesome in consequence; and, although the friction of this large anemometer is somewhat greater than that of the smaller ones, the difference in this respect is trifling; even the large instrument would apparently be kept in motion by a velocity of 64 feet per minute, or little more than 1 foot per second, and as friction must be allowed for in all cases, its amount is of no great importance, within moderate limits. It is not very easy to account for the curvature of the line given by the large instrument, when not observed in the smaller ones; it may, however, arise from one of two causes, or possibly partly from both. The large instrument is moved sensibly quicker in the circle of revolution at its outer, than at its inner extremity, while this difference of velocity in the two sides of the anemometer is less palpable in the smaller ones; and this difference may tend to cause all the instruments to depart from the straight line, but from being less in amount with small instruments, may not be observable within the velocities attained in the experiments: or, apart from this cause, all such anemometers may give curved lines when plotted in this way, but, perhaps, quicker curves in large than small instruments; considerations as to strength, portability, comparative freedom from liability to derangement, and original cost, all appear to be favourable to the use of the 6-inch or 4-inch Biram anemometer, in preference to the 12-inch ones.

The constant multiplier m, in these formula, which depends to some extent, for its amount, upon the spur gear, and the arbitrary marks and numbers on the dial, is greatest on the 6-inch, and least in the 12-inch anemometer; while, in the smallest, or 4-inch, it is intermediate; proving that it does not necessarily follow the size of the instrument, but really depends partly upon the conditions just mentioned.

The experiments from which this diagram was constructed are as follows:—

No. 4.—Table of Experiments made with the three sizes of Biram Anemometers, to ascertain the constants m *and* a *in the formula* V = m R + a *for each instrument; the true Velocities being ascertained by passing the Anemometers through a still atmosphere at known Velocities, by the Whirling Machine, in a circle of 25 feet in circumference.*

No. of Experiment.	Yellow Line, 4-in. Anemometer.					Red Line, 6-in. Anemometer (same as Blue of No. 3).					Blue Line, 12-in. Anemometer (same as Red No. 3 & Blue No. 7).				
	Velocity.			Error.		Velocity.			Error.		Velocity.			Error.	
	Number indicated by index of Anemometer = R.	Actual Velocity = V.	Velocity calculated by formula V = ·9578 R + 47·53.	More.	Less.	Number indicated by index of Anemometer = R.	Actual Velocity = V.	Velocity calculated by formula V = ·9656 R + 40·5.	More.	Less.	Number indicated by index of Anemometer = R.	Actual Velocity = V.	Velocity calculated by formula V = ·92 R + ·00477 R² + 69·18.	More.	Less.
1	107	150	150	..	..	..	..	..	..	..	19	79	78	..	1
2	110	156	..	..	..	..	..	..	..	..	46	96	..	..	..
3	132	175	..	..	..	..	..	..	..	..	55	102	..	..	..
4	132	173	..	..	..	..	..	..	..	..	67	108	..	..	..
5	142	183	..	..	..	..	..	..	..	..	93	137	..	..	..
6	152	192	193	1	..	..	..	..	..	..	117	158	..	..	..
7	167	206	..	..	..	..	..	..	..	..	119	158	..	..	..
8	173	212	..	..	..	..	..	..	..	..	151	183	..	..	..
9	180	217	..	..	..	..	..	..	..	..	186	208	..	..	..
10	200	234	..	..	..	..	..	..	..	..	185	208	..	..	..
11	203	242	..	..	..	..	..	..	..	..	215	236	..	..	..
12	205	242	244	2	..	..	..	..	..	..	257	276	..	..	..
13	209	247	..	..	..	..	..	..	..	..	267	283	..	..	..
14	249	281	..	..	..	..	..	..	..	..	268	283	..	..	..
15	250	283	..	..	..	..	..	..	..	..	288	300	..	..	..
16	210	247	..	..	..	..	..	..	..	..	305	317	318	1	..
17	275	306	..	..	..	..	..	..	..	..	313	325	..	..	..
18	273	306	..	..	..	..	..	..	..	..	313	325	..	..	..
19	287	317	..	..	..	..	..	..	..	..	327	342	..	..	..
20	286	321	..	..	..	..	..	..	..	..	333	350	..	..	..
21	337	371	..	..	..	..	..	..	..	..	345	358	..	..	..
22	368	400	401	1	..	..	..	..	..	..	378	392	392	..	..
23	..	..	..	..	..	..	..	..	..	..	382	392	..	..	..

COMPARISON OF ANEMOMETERS.

No. V. Diagram.

In consequence of the sensible difference in the formula required for the 12-inch, and for the 6-inch, and 4-inch anemometers, as exhibited in *Diagram No. IV.*, another set of experiments were made to prove whether this was owing to the construction of the larger instrument, or to some error in observation in the previous experiments; the results are given in *No. V. Diagram.*

In this diagram two sets of experiments, made with the same 12-inch anemometer, at different times, by the Whirling Machine, with a circle 25 feet in diameter, are compared with each other.

The *red* line is the same as the *blue* line of *No. IV. Diagram*, and is a curve, as has been already stated; the *blue* line is also a curve, but approaches rather more nearly to a straight line; the friction being at the same time much smaller than in the same instrument, tried in the experiments shown by *No. IV. Diagram;* so that the friction does not appear to depend so much upon the size, as upon the condition of the instrument. This result agrees with those obtained in other experiments with the 4-inch anemometer (page 232), which latter clearly prove that the friction does not vary much if the instrument itself remains unaltered, but from the construction of the larger instruments, and from the nature of the material of which their vanes are formed, they are extremely liable to become disarranged and altered in form, in fact it is most difficult to avoid putting them out of form when using them, and it is extremely probable that the alteration in the additive constant is due to this cause.*

Both the lines deduced from the experiments made with the 12-inch or large anemometers are, it will be seen, curves, and require complicated formula; while it is somewhat doubtful as to whether the departure from a straight line is due to the circular motion caused by the revolving wand of the Whirling Machine, or is inherent in the nature of the instruments themselves, in which latter case only would it arise on employing the instrument for measuring currents of air in the ordinary way.

* This view is corroborated by *No. XI. Diagram*, in which it will be observed that the constant for one of the 4-inch anemometers is altered in consequence of its falling off the wand and becoming deranged, although no alteration in the instrument was observable from the accident. *No. XII. Diagram* also elucidates this.

No. 5.—Table of Second Set of Experiments, made with a Biram's 12-inch Anemometer, with Whirling Machine, 25-feet circle (made to corroborate No. 4 Set of Experiments).

	Blue (New Series).					Red (same as Blue Nos. 4 and 7).				
	Velocity.			Error.		Velocity.			Error.	
No. of Experiment.	Number indicated by index of Anemometer = R.	Actual velocity = V.	Velocity calculated by formula V = ·9001 R + ·0018 R² + 65·6.	More.	Less.	Number indicated by index of Anemometer = R.	Actual velocity = V.	Velocity calculated by formula V = ·69 R + ·00477 R² + 68·16.	More.	Less.
1	64	96	..	..	..	19	79	78	..	1
2	77	104	..	..	..	46	96	..	..	..
3	88	114	114	..	..	55	102	..	..	..
4	93	118	..	..	..	67	108	..	..	..
5	94	121	..	..	..	93	137	..	..	..
6	95	123	..	..	..	117	158	..	..	..
7	110	133	..	..	..	119	158	..	..	..
8	134	156	..	..	..	151	183	..	..	..
9	136	158	..	..	..	186	208	..	..	..
10	143	167	..	..	..	185	208	..	..	..
11	143	167	..	..	..	215	236	..	..	..
12	150	167	170	3	..	257	276	..	..	..
13	161	185	..	..	..	267	283	..	..	..
14	170	192	..	..	..	268	283	..	..	..
15	173	192	..	..	..	288	300	..	..	..
16	175	192	..	..	..	305	317	318	1	..
17	216	233	..	..	..	313	325	..	..	..
18	227	242	..	..	..	313	325	..	..	..
19	244	258	..	..	..	327	342	..	..	..
20	262	275	..	..	..	333	350	..	..	..
21	269	283	..	..	..	345	358	..	..	..
22	272	283	..	..	..	378	392	392	..	..
23	293	308	..	..	..	382	392	..	..	..
24	295	308	..	..	..	..	..	..	..	..
25	348	358	..	..	..	..	..	..	..	..
26	357	367	..	..	..	..	..	..	..	..
27	399	408	..	..	..	..	..	..	..	..
28	403	417	..	..	..	..	..	..	..	..
29	405	417	..	..	..	..	..	..	..	..
30	410	417	417	..	..	..	..	..	..	..
31	424	433	..	..	..	..	..	..	..	..
32	448	458	..	..	..	..	..	..	..	..
33	224	250	..	..	..	..	..	..	..	..
34	346	358	..	..	..	..	..	..	..	..
35	362	375	..	..	..	..	..	..	..	..

COMPARISON OF CIRCLES.

No. VI. Diagram

Shows the effect of causing an anemometer to revolve in a 10-feet as compared with a 25-feet circle, on the Whirling Machine, with a governor

fixed downwards in both cases; the *red* line is the same as the *yellow* line in *No. III. Diagram*, and is for the 25-feet circle. On taking the circle at 10-feet, the constant additive for friction remains unaltered, but the instrument itself revolves quicker than in the larger circle for equal velocities, so that the constant multiplier is reduced.

The anemometer was the same 6-inch Biram in each case.

No. 6.—Table of Experiments made with a 6-inch Biram's Anemometer to ascertain the effect of revolving in circles of different diameters, with a governor or board fixed downward on the wand of the Whirling Machine.

Number of Experiment.	Red Line, 25 Feet Circle. (Yellow, No. 3.)					Blue Line, 10 Feet Circle.				
	Number indicated by index of Anemometer = R.	Actual Velocities = V.	Velocity calculated by formula V = 9 R + 45·3.	Error. More.	Error. Less.	Number indicated by index of Anemometer = R.	Actual Velocities = V.	Velocity calculated by formula V = 7076 R + 85·3.	Error. More.	Error. Less.
1	56	99	..	..	..	25	69	..	..	..
2	65	104	104	..	..	26	70	..	..	..
3	75	106	..	..	..	27	68	66	..	2
4	71	108	..	..	..	53	86	..	..	..
5	72	112	..	..	..	54	88	..	..	..
6	72	113	..	..	..	67	97	..	..	..
7	107	142	142	..	..	68	95	..	..	..
8	107	142	..	..	..	75	102	..	..	..
9	107	142	..	..	..	89	115	..	..	..
10	108	142	..	..	..	87	112	112	..	..
11	150	180	..	..	..	98	122	..	..	..
12	152	181	..	..	..	99	120	..	..	..
13	153	183	..	..	..	103	121	..	..	..
14	153	183	..	..	..	103	122	..	..	..
15	195	225	..	..	..	107	129	..	..	..
16	196	223	..	..	..	113	130	131	1	..
17	198	225	224	..	1	115	132	..	..	..
18	198	225	..	..	..	128	145	..	..	..
19	199	225	..	..	..	128	145	..	..	..
20	223	248	..	..	..	139	152	..	..	..
21	223	248	..	..	..	141	155	154	..	1
22	252	267	268	1	..	..	..	..	..	..
23	253	273	..	..	..	..	..	..	..	..
24	256	273	..	..	..	..	..	..	..	..

COMPARISON OF CIRCLES.—(TO CORROBORATE No. 6.)

No. VII. Diagram.

This series of experiments, like No. 6 set, give a comparison of the effect of causing anemometers to revolve in circles of different sizes,

with a 12-inch in lieu of a 6-inch anemometer, and without governors. Here, again, the instrument revolves quicker, for a given velocity through the air, in a 10-feet than in a 25-feet circle, showing that the result is not accidental, but has a cause, depending for its amount upon the size of the circle; and this fact renders it probable, that if the circles were indefinitely large, or what is equivalent, if the anemometers were moved in a straight line, through a still atmosphere, the numbers indicated by the index of the instrument would be somewhat less than those obtained in a 25-feet circle, the difference, however, would, in all probability, be small.

As this point is one of very considerable importance, in connection with the general principles of aerodynamics, the writers intend making further experiments in reference to this part of the subject.

No. 7.—Table of Experiments made with a 12*-inch Biram's Anemometer, by the Whirling Machine, with a* 25*-feet and a* 10*-feet circle, without governor boards.*

No. of Experiment.	Red Line, 10 Feet Circle.			Error.		Blue Line (same as Blue No. 4).			Error.	
	Number indicated by Index of Anemometer = R.	Actual Velocities = V.	Velocity calculated by Formula V = 75 R + ·08·09 R² + 472.	More.	Less.	Numbers indicated by Index of Anemometer = R.	Actual Velocity = V.	Velocity calculated by Formula V = ·09 R + ·00477 R² + 6·16.	More.	Less.
1	31	74	..	.	..	19	79	78	..	1
2	39	77	..	..	..	46	96	..	..	..
3	64	100	..	..	..	55	102	..	..	..
4	69	103	..	..	..	67	108	..	..	..
5	72	107	..	..	..	93	137	..	..	..
6	73	109	..	..	..	117	158	..	..	..
7	83	113	..	..	..	119	158	..	..	..
8	86	117	..	..	..	151	183	..	..	..
9	93	116	..	..	..	186	208	..	..	..
10	97	126	..	..	..	185	208	..	..	..
11	132	155	..	..	..	215	236	..	..	..
12	133	154	..	..	..	257	276	..	..	..
13	151	170	..	..	..	267	283	..	..	..
14	152	170	..	..	..	268	283	..	..	..
15	191	210	..	..	..	288	300	..	..	..
16	192	210	..	..	..	305	317	318	1	..
17	234	245	..	..	..	313	325	..	..	..
18	235	245	..	..	..	313	325	..	..	..
19	265	275	..	..	..	327	342	..	..	..
20	270	280	..	..	..	333	350	..	..	..
21	311	320	..	..	..	345	358	..	..	..
22	316	325	..	..	..	378	392	392	..	..
23	367	375	..	..	..	382	392	..	..	..
24	374	380	..	..	..	..	..	..	..	.

COMPARISON OF ANEMOMETERS.

No. VIII. Diagram.—Lines formed by Experiments made with Combes' Anemometer.

This is the instrument chiefly employed on the continent, and is the invention of Mons. Combes; it is a revolving instrument, being put into motion by the impact of the wind, upon four vanes, fixed like the sails of a windmill, at an angle with the direction of the wind, and requires the application of a formula to reduce the numbers indicated by its index to actual velocities.

In the various experiments that have been made with these instruments on the continent, it has been found that the excess of the actual wind velocities, over the particular wind velocities which are required to overcome their frictional resistance, is simply proportional to the number of revolutions performed by them in the unit of time; or, what is the same, to the numbers indicated by the pointers, giving rise to an expression of the form of $V = m R + a$, by means of which, the velocity of the wind V can be found when we know the number of revolutions R, of the instrument, in the unit of time; a and m being constants for the same instrument, whatever be the velocity V, or revolutions R.

The above expression is the equation to a straight line. The constants a and m, can be determined for any instrument, by means of two experimental trials of the number of revolutions corresponding to different ascertained wind velocities; thus, if V and R are the velocity and corresponding number of revolutions or indications given by the pointers in the unit of time, in one of such trials, and V', and R', the same, respectively, on the other trial,

$$\text{then } V = m R + a$$

$$\text{and } V' = m R' + a$$

$$\text{from whence } m = \frac{V - V'}{R - R'}$$

$$\text{and } a = \frac{V' R - V R'}{R - R'}$$

The irregularities in the line made by this instrument, are, doubtless, caused by errors in observation, and derangement of the pointers, as it is much more difficult to read off than Biram's instrument, under the peculiar circumstances of revolving on a wand in a circle; but these irregularities would probably not exist, when using the instrument in the ordinary way for measuring a current of air. The line for the Biram's anemometer is more uniform, because it can be read off with more ease and accuracy in this kind of experiment.

No. 8.—Table of Experiments with Combes and Robinson's Anemometers, compared with Biram's Anemometer, on Whirling Machine, 25-feet circle.

No. of Experiment.	Combes' Red Line.					Robinson's Anemometer.					Yellow Line. Biram's 6-in (same as Yellow No. 9.)					
	Velocity.			Error.		Velocity.			Error.		Velocity.				Error.	
	Number indicated by Index of Anemometer = R.	Actual Velocities = V.	Velocity calculated by formula V = 798 R + 78.	More.	Less.	Number indicated by Index of Anemometer = R.	Actual Velocities = V.	Velocities calculated by formula V =	More.	Less.	Number indicated by Index of Anemometer = R.	Actual Velocities = V.	Velocities calculated by formula V = 3668 R + error.	Velocities calculated by formula V = 7851 R + 000648 R + 6632	More.	Less.
..	201	225	226	..	..	67	149	..	..	..	61	125	..	..	..	..
..	213	233	..	..	..	327	368	..	..	..	67	125	124	124	..	1
..	317	308	..	..	..	542	587	..	..	..	140	187	..	..	..	..
..	324	317	..	..	..	777	798	..	..	..	145	200	..	..	..	..
..	325	325	..	..	..	..	..	..	..	..	187	225	..	..	..	..
..	332	325	..	..	..	..	..	..	..	..	190	237	..	..	..	..
..	336	358	..	..	..	..	..	..	..	..	197	237	..	..	..	..
..	433	408	..	..	..	..	..	..	..	..	200	250	..	..	..	..
..	359	342	..	..	..	..	..	..	..	..	200	250	..	..	..	..
..	369	358	..	..	..	..	..	..	..	..	215	250	..	..	..	..
..	433	392	..	..	..	..	..	..	..	..	235	275	..	..	..	..
..	448	408	..	..	..	..	..	..	..	..	287	337	..	..	..	..
..	480	442	..	..	..	..	..	..	..	..	292	337	..	..	..	..
..	491	433	..	..	..	..	..	..	..	..	367	412	..	..	..	..
..	529	458	460	2	..	..	..	..	..	..	375	412	..	..	..	..
..	529	467	..	..	..	..	..	..	..	..	418	450	..	..	..	..
..	552	475	..	..	..	..	..	..	..	..	422	450	..	..	..	..
..	613	533	..	..	..	..	..	..	..	..	442	487	..	..	..	..
..	616	533	..	..	..	..	..	..	..	..	452	487	..	..	..	..
..	618	542	..	..	..	..	..	..	..	..	477	512	..	..	..	..
..	618	533	..	..	..	..	..	..	..	..	482	512	..	..	..	..
..	641	550	..	..	..	..	..	..	..	..	485	512	..	..	..	..
..	690	583	..	..	..	..	..	..	..	..	577	600	..	..	.	..
..	722	608	..	..	..	..	..	..	..	..	592	612	..	..	..	..
..	752	625	..	..	..	..	..	..	..	..	605	625	..	..	..	..
..	756	633	..	..	..	..	..	..	..	..	617	637	..	..	..	..
..	740	617	..	..	..	..	..	..	..	..	685	712	..	..	..	..
..	797	650	..	..	..	..	..	..	..	..	690	712	..	..	..	..
..	811	675	678	3	..	..	..	..	..	..	750	775	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	775	800	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	785	812	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	785	812	811	811	..	1

MOVING ANEMOMETERS IN A STRAIGHT LINE THROUGH A STILL ATMOSPHERE.

No. IX. Diagram.

This diagram exhibits the results of different sets of experiments made with a 6-inch and 4-inch Biram's anemometer, by a person walking in the still atmosphere of a large granary, and carrying the instrument in his hand; and another set (for the purpose of comparison with those made as above)

6 inch Bir

by the Whirling Machine, in a 25-feet circle, without governors on the revolving wand. The results obtained in these experiments appear to be both remarkable and important, inasmuch as they indicate that the formula, deduced from the walking experiments, do not agree, even within moderate limits, with those obtained by the use of the Whirling Machine; and it becomes a question as to whether the results of either mode are reliable, and if either, as to which mode is so.

All the lines in this diagram are more or less curved. The *yellow* line relating to the revolving experiments is, however, less curved than the other lines, relating to the experiments made by walking in a straight line, and carrying the instrument through a still atmosphere; the *yellow* line, indeed, may be regarded as being nearly straight. Of the more recent experiments, the *brown* line may be taken as approaching the straight line; also the *black* line up to (a) where it rapidly falls off. This is probably owing to errors at the high velocities.

The *red* line obtained by walking in a straight line is much more curved than the *yellow* line of the 25-feet circle, the multiplier (m) of the numbers indicated by the index of the anemometer being much smaller, and the multiplier of the square of the numbers indicated by the index of the anemometer being very much larger in the experiments made by walking in a straight line than in the revolving experiments. It appears to be anomalous that the lines relating to experiments in a 10-feet circle should be more curved than those relating to experiments in a 25-feet circle, on the one hand; while the line relating to experiments made in a straight line should, on the other hand, be more curved than either.

Future experiments may possibly throw some light upon this apparent anomaly.

It is stated in Weisbach's Mechanics, that from the experiments of Du Buat and those of Thibault, it would appear that the forces of still air against a flat surface, moved at different velocities through it in a straight line, are proportional to the forces of impact of winds of the same velocities, but less than them in the ratio of 1·4 to 1·85; so that if V_r be the velocity of the wind, and V_m that of the body, in the two cases, then when the velocities are such as to make the resistance in the one case equal to the force of impact in the other, we have $1{\cdot}85\ V_r^2 = 1{\cdot}4\ V_m^2$

$$\text{and hence } V_r = \sqrt{\frac{1{\cdot}4}{1{\cdot}85}}\ V_m = 0{\cdot}87\ V_m$$

from which we see that the velocity of wind only appears to require to be 0·87 of that of a body moved through still air in a straight line, to

give rise to the same force against the body; and hence it may be that the velocities calculated from our formula, deduced from the walking or Whirling Machine experiments, would require, when the anemometer is employed in the ordinary way for measuring a current of air, to be multiplied by 0·87, to give the true velocity of the wind; but on this point we entertain very grave doubts, as such results do not appear, *a priori*, to be probable, and the subject is one in which mistakes are very liable to occur. Further experiments may possibly illustrate this part of the subject.

In like manner, when a flat surface is moved against a still atmosphere in a circle, the experiments of Hutton, Borda, and Thibault, appear to indicate that at a given velocity the force or resistance is only about 1·5, compared with a force of 1·85 for the same velocity when the flat surface is at rest, and the air moves, as a wind, against it; so that if V_o be the velocity of a flat surface moving in a circle, and V_r the velocity of a wind giving rise to the same force, then, in order that the force in the one case may be equal to the resistance in the other, we have the velocities such that

$$1{\cdot}85\ V_r^2 = 1{\cdot}5\ V_o^2$$

$$\text{from whence } V_r = \sqrt{\frac{1{\cdot}5}{1{\cdot}85}}\ V_o = {\cdot}9\ V_o$$

from which it would appear that the velocities of wind, as deduced from the formula found by the experiments made with the Whirling Machine, should be reduced by multiplying them by ·9 in order to get the actual velocities of the wind. There is, however, said to be more grave doubts still as to the correctness of this conclusion, and for the present it is preferred to leave it out of the formula given.

The discrepancy between the *yellow line*, in *No. IX. Diagram*, representing V_o and the *blue* and *red* lines representing V_m are much greater than the differences just alluded to would appear to indicate, and hence there is reason to suppose that the data are not reliable; indeed, it may be seen that Weisbach, in adopting 1·85, 1·4, and 1·5 as multipliers of the motive column to give the force or resistance due to a wind, to moving a flat surface in a straight line through still air, and then in a circle, respectively, makes no distinction between a large and a small circle, while a glance at *Diagram No. VII.* appears to show, that the size of the circle has considerable influence upon the amount of the resistance the body meets with in its revolutions through still air at any velocity.

It should, however, also be stated that the discrepancies between the *yellow* line on the one hand, and the *blue*, *red*, and other lines on the

other hand, in *No. IX. Diagram*, chiefly prevail at the higher velocities, and probably arise from the errors of observation, owing to the experimenter having to run at considerable speeds; the jolting motion arising from this, and the disturbance of the air by his body, must be considerable. The formula for the *brown* and *green* lines is obtained only up to a velocity of 500 feet per minute, up to which point the diagram exhibits a straight line, conforming very closely with that given by the Whirling Machine.

The height of a column of a fluid, h, in feet, required to generate a velocity of V_1 in feet per second, apart from friction, is expressed by

$$h_1 = \frac{V_1^2}{2\,g}$$

when $g = 32\frac{1}{6}$, giving

$$h_1 = \frac{V_1^2}{64\frac{1}{3}}$$

or, where h_2 is the height of the column due to V_2, the velocity in feet per minute, this becomes

$$h_2 = \frac{V_2^2}{231{,}600}$$

and from the experiments of the authors just mentioned, it would appear that the impact of a fluid in motion would support a vertical column of the height f_r in feet, expressed by

$$f_r = \frac{1{\cdot}85\ V_2^2}{231{,}600} = \frac{1{\cdot}85\ V_1^2}{64\frac{1}{3}}$$

$$\text{or } f_r = \frac{V_2^2}{125{,}189} = \frac{V_1^2}{34{\cdot}77}$$

While if the fluid is at rest, and the body (having in each case a flat surface) is moved in a straight line, the resistance f_m in height in feet of a column of the fluid would only amount to

$$f_m = \frac{1{\cdot}4\ V_2^2}{231{,}600} = \frac{1{\cdot}4\ V_1^2}{64\frac{1}{3}}$$

$$\text{or } f_m = \frac{V_2^2}{165{,}429} = \frac{V_1^2}{45{\cdot}952}$$

or if the body were moved in a circle the resistance would support a column of the fluid f_o feet in height found by

$$f_o = \frac{1{\cdot}5\ V_2^2}{231{,}600} = \frac{1{\cdot}5\ V_1^2}{64\frac{1}{3}}$$

$$\text{or } f_o = \frac{V_2^2}{154{,}400} = \frac{V_1^2}{42{\cdot}889}$$

No. 9.—Table of Experiments made by walking 500 *feet in a granary in a still atmosphere, with a* 6*-inch and* 4*-inch Biram's Anemometer in the hand, compared with experiments made with the same Anemometer on the Whirling Machine.*

WALKING.

Number of Experiment.	Red Line, 1st Trial. Number indicated by index of Anemometer = R.	Red Line, 1st Trial. Actual Velocities = V.	Red Line, 1st Trial. Velocity calculated by Formula V = 6 R + ·000865 R² + 64·53.	Red Line, 1st Trial. Error. More.	Red Line, 1st Trial. Error. Less.	Blue Line, 2nd Trial. Number indicated by index of Anemometer = R.	Blue Line, 2nd Trial. Actual Velocity = V.	Blue Line, 2nd Trial. Velocity calculated by Formula V = ·852 R + ·0004212 R² + 43·35.	Blue Line, 2nd Trial. Error. More.	Blue Line, 2nd Trial. Error. Less.
1	45	96	..	..	..	78	108	..	..	..
2	59	103	103	..	..	82	116	115	..	1
3	68	111	..	..	..	83	112	..	..	..
4	95	125	..	..	..	93	133	..	..	..
5	95	125	..	..	..	103	144	..	..	..
6	97	129	130	1	..	110	149	..	..	..
7	98	129	..	..	..	184	219	..	..	..
8	110	141	..	..	..	187	242	..	..	..
9	111	144	..	..	..	192	227	..	..	..
10	112	139	..	..	..	191	227	..	..	..
11	116	147	145	..	2	203	262	..	..	..
12	121	151	..	..	..	204	242	..	..	..
13	134	174	..	..	..	208	256	..	..	..
14	177	197	..	..	..	212	241	..	..	..
15	186	211	..	..	..	215	246	..	..	..
16	191	208	..	..	..	250	285	282	..	3
17	194	214	..	..	..	285	326	..	..	..
18	198	225	..	..	..	284	313	..	..	..
19	200	222	..	..	..	296	325	..	..	..
20	220	234	..	..	..	314	349	..	..	..
21	243	270	..	..	..	325	395	..	..	..
22	243	283	..	..	..	335	389	..	..	..
23	272	312	..	..	..	334	384	..	..	..
24	308	349	..	..	..	335	389	..	..	..
25	310	344	..	..	..	340	384	..	..	..
26	317	337	..	..	..	359	434	..	..	..
27	324	358	..	..	..	375	441	..	..	..
28	330	357	..	..	..	349	416	..	..	..
29	388	435	..	..	..	404	476	..	..	..
30	422	468	..	..	..	410	468	..	..	..
31	455	535	..	..	..	414	517	..	..	..
32	520	625	..	..	..	447	508	..	..	..
33	541	652	..	..	..	646	769	..	..	..
34	549	683	..	..	..	657	811	..	..	..
35	549	638	..	..	..	707	769	..	..	..
36	566	682	682	..	..	710	789	..	..	..

Number of Experiment.	Brown Line, 3rd Trial. Number indicated by index of Anemometer = R.	Brown Line, 3rd Trial. Actual Velocity = V.	Brown Line, 3rd Trial. Velocity calculated by Formula V = ·9 R + 42	Brown Line, 3rd Trial. Error. More.	Brown Line, 3rd Trial. Error. Less.	Green Line, 4th Trial. (Taken to "a.") Number indicated by index of Anemometer = R.	Green Line, 4th Trial. Actual Velocity = V.	Green Line, 4th Trial. Velocity calculated by Formula V = R + 46.	Green Line, 4th Trial. Error. More.	Green Line, 4th Trial. Error. Less.	Machine, 25-feet circle. Yellow Line. (Same as Yellow No. 9.) Number indicated by index of Anemometer = R	Yellow Line. Actual Velocity = V.	Yellow Line. Velocity calculated by Formula V = ·9368 R + 60·92	Yellow Line. Velocity calculated by Formula V = ·8851 R + ·0000812 R² + 65·92	Yellow Line. Error. More.	Yellow Line. Error. Less.
1	51	91	91	..	..	90	140	..	..	..	61	125	..	..	..	..
2	100	125	..	..	..	91	132	..	..	..	67	123	124	124	..	1
3	93	131	..	..	..	108	149	142	..	..	140	187	..	..	..	..
4	168	190	..	..	..	131	190	..	..	..	145	200	..	..	..	..
5	184	203	..	..	..	144	186	..	..	..	187	235	..	..	..	..
6	171	215	..	..	..	145	190	..	..	..	190	237	..	..	..	..
7	197	232	..	..	..	157	198	..	..	..	197	237	..	..	..	..
8	218	232	..	..	..	160	230	..	..	..	200	250	..	..	..	..
9	212	233	237	..	1	237	245	..	..	..	200	250	..	..	..	..
10	207	234	..	..	..	240	276	..	..	..	215	230	..	..	..	..
11	197	250	..	..	..	307	319	..	..	..	235	275	..	..	..	..
12	261	300	..	..	..	355	380	..	..	..	247	337	..	..	..	..
13	276	303	..	..	..	352	340	..	..	..	292	337	..	..	..	..
14	245	306	..	..	..	355	399	401	2	..	367	412	..	..	..	..
15	237	306	..	..	..	380	434	..	..	..	375	412	..	..	..	..
16	259	313	..	..	..	400	431	..	..	..	418	450	..	..	..	..
17	236	333	..	..	..	418	467	..	..	..	422	450	..	..	..	..
18	317	353	..	..	..	431	467	..	..	..	442	497	..	..	..	..
19	307	357	..	..	..	441	480	..	..	..	452	487	..	..	..	..
20	410	440	441	..	..	517	570	..	..	..	477	512	..	..	..	..
21	..	..	..	..	..	523	570	571	1	..	492	512	..	..	..	..
22	..	..	..	..	..	650	780	..	..	..	485	512	..	..	..	..
23	..	..	..	..	..	..	..	..	..	..	577	600	..	..	..	..
24	..	..	..	..	..	..	..	..	..	..	592	612	..	..	..	..
25	..	..	..	..	..	..	..	..	..	..	605	625	..	..	..	..
26	..	..	..	..	..	..	..	..	..	..	617	637	..	..	..	..
27	..	..	..	..	..	..	..	..	..	..	645	714	..	..	..	..
28	..	..	..	..	..	..	..	..	..	..	690	712	..	..	..	..
29	..	..	..	..	..	..	..	..	..	..	750	775	..	..	..	..
30	..	..	..	..	..	..	..	..	..	..	775	800	..	..	..	..
31	..	..	..	..	..	..	..	..	..	..	783	812	..	..	..	..
32	..	..	..	..	..	..	..	..	..	..	785	812	811	811	..	1
33	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
34	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
35	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
36	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

No. 10 *Series of Experiments*

Was made for the purpose of observing whether the action of Biram's anemometer varied much with the condition of the instrument, *i.e.*, whether the same formula and constants were required for the same instrument when properly cleaned and oiled, and again, after being much used and in a dirty condition; and it is certainly satisfactory to find, as will be

observed in the diagram, that the action of the same instrument is very little altered through these varied conditions.

The dotted line on this diagram shows the velocity found by correcting the readings of the anemometer by the formula (for this particular instrument), V = 1·017 R + 30; and it will be remarked how very close the line approximates to the true velocity of the instrument passing through the air, as found by the Whirling Machine.

No. 10.—*Table of Experiments made with a 6-inch Biram's Anemometer, in clean and dirty conditions respectively, on the Whirling Machine in a 25-feet circle.*

No. of Experiment.	Red Line.—Instrument Clean.					Blue Line.—Instrument Dirty.				
	Number indicated by Index of Anemometer = R.	Actual Velocity = V.	Velocity calculated by Formula V = 1·017 R + 30.	Error. More.	Error. Less.	Number indicated by Index of Anemometer = R.	Actual Velocity = V.	Velocity calculated by Formula V = R + 30.	Error. More.	Error. Less.
1	93	125	125	..	..	62	100	..	..	..
2	120	150	152	2	..	80	119	..	..	..
3	133	162	165	3	..	100	137	..	..	..
4	412	450	449	..	1	365	400	..	..	..
5	412	450	449	..	1	395	427	..	..	..
6	422	450	459	9	..	425	462	..	..	..
7	427	462	464	2	..	585	625	..	..	..
8	582	625	622	..	3	585	625	..	..	..
9	585	625	625	..	..	..	..	..	..	..
10	592	637	632	..	5	..	..	..	..	..

No. XI. Diagram

Exhibits a series of lines formed by various 4 and 6-inch Biram's anemometers, with which experiments have been tried. It will be observed that, although the general tendency of the lines formed by the different anemometers is in the same direction, thus giving one general form of formula applicable to all of them; still each anemometer has a decided line of its own, requiring that special constants, found by direct experiment, should be applied to each instrument. In making one of the experiments, the anemometer fell off the wand of the Whirling Machine (* in *blue* line), and although it sustained no apparent damage, still the line made by this instrument was altered at and from this point. The instrument was apparently not damaged, but the constants required for the correction of its readings were altered, owing, possibly, to some alteration in the form of the vanes; showing that although, as previously explained (No. 10 series), the fact of the instrument being in a clean or dirty condition, does not seriously affect its readings; still any sudden

shock, or other violent treatment tending to vary the form of the vanes, or otherwise alter the mechanical condition of the instrument, would do so.

But even in this case the discrepancy caused by the fall seems to be much less in amount than the inaccuracy of the original readings; and the application of the formula, as first found, would still render the readings much more correct than if they were used in their uncorrected state.

No. 11.—*Table of Experiments made with several Anemometers (Biram's) on Whirling Machine, in* 25*-feet circle, to find constants* m *and* a.

No. of Experiment.	Blue Line, No. 12.—4-in. Biram.					Red Line, No. 14.—4-in. Biram.					Yellow Line, No. 4.—4-in. Biram.				
	Number indicated by index of Anemometer = R.	Actual Velocity = V.	Velocity calculated by Formula V =	Error. More.	Error. Less.	Number indicated by index of Anemometer = R.	Actual Velocity = V.	Velocity calculated by Formula V =	Error. More.	Error. Less.	Number indicated by index of Anemometer = R.	Actual Velocity = V.	Velocity calculated by Formula V =	Error. More.	Error. Less.
1	205	250	..	..	..	187	237	..	..	..	77	131	..	..	..
2	210	262	..	..	..	200	250	..	..	..	82	137	..	..	..
3	215	262	..	..	..	255	300	..	..	..	182	225	..	..	..
4	340	387	..	..	..	337	387	..	..	..	200	237	..	..	..
5	345	387	..	..	..	340	387	..	..	..	230	262	..	..	..
6	360	400	..	..	..	350	400	..	..	..	242	275	..	..	..
7	405	462	..	..	..	477	537	..	..	..	312	350	..	..	..
8	412	475	..	..	..	480	537	..	..	..	320	362	..	..	..
9	437	500	..	..	..	490	550	..	..	..	375	412	..	..	..
10	440	500	..	..	..	..	..	..	..	..	460	500	..	..	..
11	..	..	..	..	..	..	..	..	..	..	487	525	..	..	..
12	..	..	..	..	..	..	..	..	..	..	510	550	..	..	..

	Brown Line, No. 13.—4-in. Biram.					Black Line, No. 11.—4-in. Biram.					Green Line, No. 8.—6-in. Biram.				
1	77	118	..	..	..	76	125	..	..	..	87	125	..	..	..
2	112	150	..	..	..	107	150	..	..	..	102	137	..	..	..
3	152	187	..	..	..	110	156	..	..	..	112	150	..	..	..
4	342	387	..	..	..	335	375	..	..	..	295	337	..	..	..
5	357	400	..	..	..	372	412	..	..	..	337	375	..	..	..
6	377	412	..	..	..	385	425	..	..	..	342	385	..	..	..
7	377	412	..	..	..	..	..	..	..	..	440	487	..	..	..
8	460	500	..	..	..	492	537	..	..	..	450	500	..	..	..
9	500	537	..	..	..	497	537	..	..	..	452	500	..	..	..
10	520	562	..	..	..	507	550	..	..	..	557	612	..	..	..
11	..	..	..	..	..	..	..	..	..	..	640	700	..	..	..

No. 12 *Series of Experiments*

Was made for the purpose of observing the comparative rates of revolution of the same Biram's anemometer, when passed through a still atmosphere, by the Whirling Machine, in the first instance with its back, and again with its face towards the direction of its motion; the former being the ordinary mode of using these instruments.

As there were considerable differences in the results given by these

experiments, evidently depending upon whether the front or the back of the instrument received the impulse of the air, so that when plotted to form a diagram, the lines appeared considerably apart from each other, showing that the same formula could not apply to the instrument under the variation of conditions involved in the experiments, another series of similar experiments, No. 12*b*, was made, further to test the truth of the conclusion indicated by the former series. The results of these experiments only served to confirm the former ones.

The two *blue* lines (*Diagram No. XII.*) are formed from *No.* 12*a series of Experiments*, and the two *red* lines from *No.* 12*b series;* the dotted line in each case being that given when the back of the anemometer received the impulse of the current, as is correct in practice.

These results prove that the *additive* constant remains the same in the same instrument when used either side foremost, but that, on the other hand, the amount of the necessary *multiplicative* constant depends upon the form of the wands receiving the impulse of the wind, as had been anticipated and mentioned in the remarks upon *Nos.* 10 *and* 11 *series.*

No. XII. Diagram (1st Series, 12*a).—Table of Experiments made with a 4-inch Biram's Anemometer on the Whirling Machine, in a 25-feet circle, to ascertain the difference between the Anemometer going the back to current and face to current.*

No. of Experiment.	Blue Line, B.—Anemometer going back to current.					Blue Line, A.—Anemometer going face to current.				
	Number indicated by Index of Anemometer = R.	Actual Velocity = V.	Velocity calculated by Formula V = 1·01 R + 41.	Error. More.	Error. Less.	Number indicated by Index of Anemometer = R.	Actual Velocity = V.	Velocity calculated by Formula V = 989 R + 41.	Error. More.	Error. Less.
1	172	212	214	..	..	157	187	187	..	..
2	182	225	..	..	..	192	218	..	..	..
3	315	362	..	..	..	240	262	..	..	..
4	317	362	361	..	1	290	312	..	..	..
5	405	450	..	..	..	307	325	326	1	..
6	417	462	462	..	..	332	350	..	..	..
	..	..	..	..	..	425	437	..	..	..
	..	..	..	..	..	450	462	..	..	..
	..	..	..	..	..	450	462	460	..	2

No. XII. Diagram (2nd Series, 12b).—Table of Experiments made with a 4-inch Biram's Anemometer on the Whirling Machine, in a 25-feet circle, to ascertain the difference between the Anemometer going the back to current and face to current.

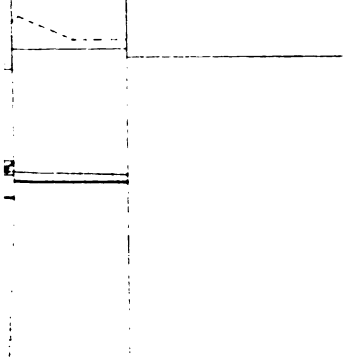
No. of Experiment.	Red Line, D.—Anemometer going back to current.					Red Line, C.—Anemometer going face to current.				
	Number indicated by index of Anemometer = R.	Actual Velocity = V.	Velocity calculated by Formula V = 98 R + 41.	Error. More.	Error. Less.	Number indicated by index of Anemometer = R.	Actual Velocity. = V.	Velocity calculated by Formula V = 98 R + 41.	Error. More.	Error. Less.
1	60	106	..	..	..	112	144	145	1	..
2	65	109	..	..	..	117	150	..	..	..
3	122	162	161	..	..	256	275	..	..	..
4	135	172	..	..	..	297	312	..	..	..
5	213	250	..	..	..	390	400	..	..	..
6	230	262	..	..	..	440	450	..	..	..
7	317	350	..	..	..	467	475	475	..	..
8	367	400	..	..	..	..	..	..	..	..
9	442	475	474	..	..	..	..	..	..	..

In general principles the anemometers of Whewel and Osler are similar to those of Combes and Biram, but by additional apparatus the two former are made self-registering, both in reference to the force and direction of the wind; this, of course, adds to the friction of the instrument, and they are not, therefore, adapted for ascertaining the velocities of feeble currents.

The anemometer of Dr. Robinson is constructed on the assumption that the force of impact of the air against hollow hemispherical cups is twice as great on the concave as on the convex side of the cups, and that the vanes revolve at the rate of $\frac{1}{3}$ of the velocity of the current, except in so far as the velocity of revolution is modified by friction.

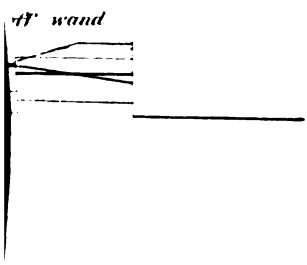
The mechanism of this instrument is very strong, and allows of the revolutions being recorded throughout a whole day; it would, therefore, be a very suitable anemometer to have near a furnace, or in the principal intake or return from a mine.

T CIR



SAN FRANCISCO. INSTITUTE

CLE.



CIRCL

raphed by And" Reid, Newcastle upon Tyne.

PRESSURE ANEMOMETERS.

Perhaps amongst the best known of the pressure anemometers are Mons. Bongui's, Dr. Lind's, that of Mons. de Henaut, described by Ponson, and Mr. Dickinson's, one of Her Majesty's Inspectors of Mines. The anemometer of Mons. Bongui consists of an apparatus like a spring balance, furnished with a float-board or plain surface of given area, and the pressure or impulse is indicated by marks on the sliding rod of the spring; it is figured and described in the "Edinburgh Encyclopædia."

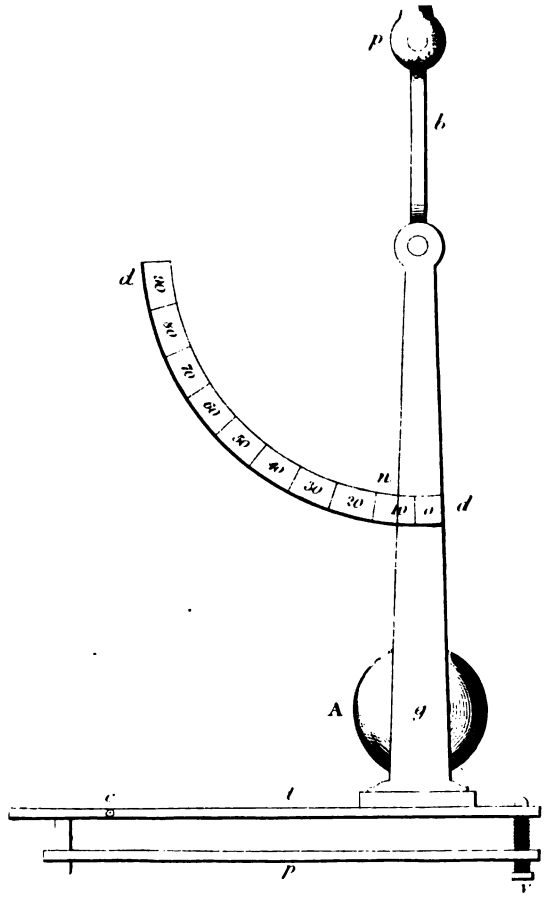
The anemometer of Dr. Lind resembles the photometer of Pitôt; it determines the velocity of the wind by its action on a small quantity of water in a U shaped tube; as the same instrument is much used in coal mines as a water-gauge for indicating the difference of pressure between the downcast and upcast air-column, it will not be at all necessary to give a detailed description of it. From numerous experiments, Dr. Lind considered that the pressure of the wind in direct impulse is nearly proportional to the square of its *velocity*. The following table is calculated from this, but considerably enlarged by other experiments.

Table of the Force and Velocity of different Winds for the Graduation of Anemometers. (Edinburgh Encyclopædia.)

Height of the column of water in Dr. Lind's Anemometer.	Force on a sq. foot in pounds avoirdupois.	Force on a sq. foot in pounds, ounces, and drams avoirdupois.			Feet in one second.	Miles in one hour.	Feet in one second.	Miles in one hour.	Character of the Winds.
					Computed from Rouse's experiments.		Computed from Dr. Hutton's experiments.		
		lbs.	oz.	dr.					
0·0009515	0·005	0	0	1·280	1·43	1	1·63	1·11	Hardly perceptible .....Rouse.
0·0038060	0·020	0	0	5·120	2·93	2	3·26	2·22	Just perceptible .....Rouse.
0·0083732	0·044	0	0	11·264	4·40	3	4·84	3·30	
0·0133210	0·079	0	1	4·224	5·87	4	6·52	4·44	Gentle winds .....Rouse.
0·023	0·123	0	1	15·488	7·33	5	8·09	5·51	
0·025	0·130	0	2	1·280	7·55	5·14	8·33	5·67	A gentle wind .....Lind.
0·050	0·260	0	4	2·560	10·67	7·27	11·77	8·00	Pleasant wind.....Lind.
0·092	0·492	0	7	13·952	14·67	10·00	16·16	11·01	Pleasant brisk gale ....Rouse.
0·10	0·521	0	8	5·378	15·19	10·35	16·66	11·35	Fresh breeze .....Lind.
0·11	1·107	1	1	11·392	22·00	15·00	24·30	16·57	Brisk gale .....Rouse.
0·368	1·968	1	15	7·808	29·34	20·00	32·39	22·00	Very brisk.....Rouse.
0·5	2·604	2	9	10·624	33·74	23·00	37·26	25·40	Brisk gale.....Lind.
0·585	3·075	3	1	3·200	36·67	25·	40·51	27·62	Very brisk.....Rouse.
0·84	4·429	4	6	13·824	44·01	30·	48·60	33·13	High wind.....Rouse.
1·0	5·208	5	3	5·248	47·73	32·54	52·70	35·93	High wind.....Lind.
1·146	6·027	6	0	6·912	51·34	35·	56·69	38·65	
1·5	7·873	7	13	10·688	58·68	40·	64·79	44·00	Very high .....Rouse.
1·9	9·963	9	15	6·528	66·01	45·	72·89	49·69	Great storm .....Denham.
2·0	10·417	10	6	10·496	67·50	46·02	74·53	50·81	Very high .....Lind.
2·68	12·300	12	4	12·800	73·35	50·	81·02	55·24	Storm or tempest .....Rouse.
3·	15·625	15	10	00·000	82·67	56·37	91·28	62·23	Storm .....Lind.
3·37	17·715	17	11	7·040	88·02	60·	97·20	66·27	Great storm .....Rouse.
4·	20·833	20	13	5·248	95·46	65·08	105·40	71·86	Great storm .....Lind.
4·08	21·435	21	6	15·360	96·82	66·	106·92	74·79	Great storm .....La Condamina.
5·	26·041	26	0	10·496	106·72	72·76	117·84	80·10	Very great storm .....Lind.
6·	31·490	31	7	13·440	117·36	80·	129·59	88·54	Hurricane.....Rouse.
6·	31·250	31	4	00·000	116·91	79·71	129·09	88·01	Hurricane.....Lind.
7·	36·548	36	8	12·288	126·43	86·20	139·65	95·21	Great hurricane .....Lind.
8·	41·667	41	10	10·752	135·00	92·04	149·07	101·63	Very great hurricane....Lind.
9·	46·875	46	14	00·000	143·11	97·57	168·11	107·80	Most violent hurricane..Lind.
9·36	49·200	49	3	3·200	146·70	100·	162·04	110·48	Hurricane that tears up trees and throws down buildings.....Rouse.
10·	52·083	52	1	5·248	150·93	102·90	166·66	113·63	
11·	57·293	57	4	11·008	158·29	107·92	171·72	117·08	
11·12	58·450	58	7	3·200	160·00	109·	176·55	120·37	Observed by Rochon.
12·	62·500	62	8	0·000	165·34	112·73	182·57	124·47	
1	2	3			4	5	6	7	8

Borda, however, found that the force of the wind was greater by $\frac{1}{10}$ part than Rouse's table gives. Hutton also showed that the forces at very great velocities increased in a somewhat higher ratio than the squares of the velocity.

Henaut's anemometer, a figure of which is annexed (*Drawing No. XIII.*), is similar in its principle and action to that of Mr. Dickinson; in the latter the impulse is received on a plain surface of oiled skin about 3 inches square, suspended from the top, the variations of which, from



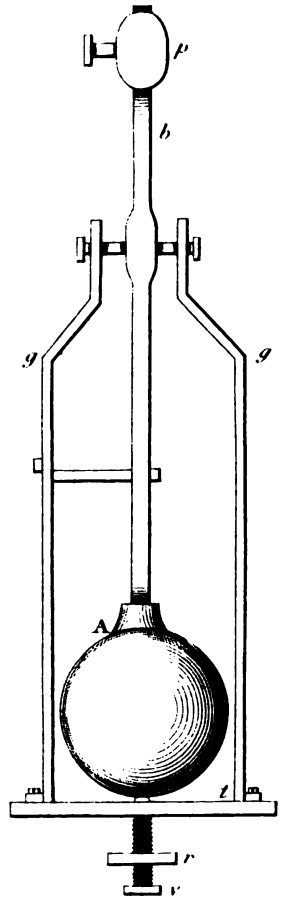
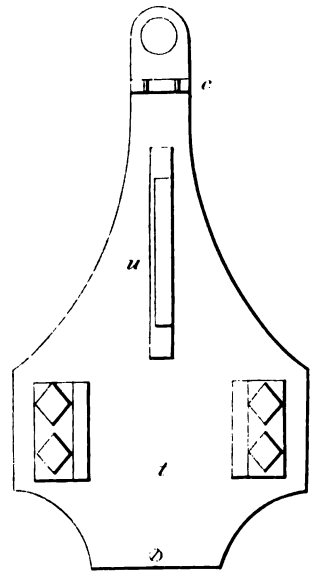


Fig.9.



SCALE

1 2

Proceedings N° of E I of M E 1861-2. Birmingham Meeting.

A Reid Lith Newcastle

the perpendicular, are noted on a scale which is marked off by direct experiments. This instrument is extremely portable, and not easily put out of order; but whilst it possesses the great value, with other instruments of this class, of not requiring any watch or other means of noting the time, it is, in common with them, subject to the great disadvantage of vibrating continually, especially in a rapid current; and of not recording the variation of the velocity within limits of 20 feet per minute; it is, however, very useful in steady currents of from 200 to 700 feet per minute.

Drawings and descriptions of several other ingenious anemometers will be found in the "Edinburgh Encyclopædia."

COMPLEX ANEMOMETERS.

The principle of the interesting method proposed by Professor Leslie, for finding the velocity of an air-current by its cooling action, can be studied at length in his "Treatise on Heat." From his experiments he deduced the following:—"A thermometer is held in the open still atmosphere, and the temperature marked; it is then warmed by the application of the hand, and the time noted which it takes to sink back to the normal point; this is termed the fundamental measure of cooling. The same observation is made on exposing the bulb to the impression of the wind, and the time required for the bisection of the interval of temperatures is termed the occasional measure of cooling; then, divide the fundamental by the occasional measure of cooling, and the increase of the quotient above unity, being multiplied by $4\frac{1}{2}$, will express the velocity of the wind in miles per hour."

As many of the irregularities in the results obtained from the use of revolving anemometers, as exhibited in the various experiments that have been described, were neither foreseen nor anticipated by the writers when they ventured to give notice of their intention to read a paper on this subject at the present meeting, the results obtained are not so satisfactory and conclusive as they could have wished.

It is, however, of some importance to exhibit the defects of the various modes at present employed for the measurement of air in mines; and the writers venture to hope, that at no distant day they may, by the further prosecution of their experiments, be able to lay before the members of this Institute some more satisfactory mode of effecting this very desirable object with sufficient accuracy.

DISCUSSION

ON

MESSRS. ATKINSON AND DAGLISH'S PAPER ON THE FRICTION OF ANEMOMETERS.

Mr. DICKINSON—I can hardly allow this subject to pass without saying a few words to the meeting. I have examined the machine to which Mr. Atkinson and Mr. Daglish have called attention, for the purpose of ascertaining the amount of friction, and I think it is the most perfect instrument of the kind which we have in this kingdom, or, indeed, anywhere else. It is about nine years since I examined the mode by which the friction of Monsieur Combes' anemometers was ascertained. That instrument was about four feet long, and had to be held in the hand. It was by no means a very accurate mode, but probably the best then in use. I then got an instrument made, somewhat on the same principle as the one which Mr. Daglish has since constructed; only the one I had constructed had no counter to register the number of revolutions, which require to be counted. With that exception, the two are almost identical. With respect to what Mr. Atkinson has said as to the formula for Biram's anemometers, I think that, if he will extend his experiments, he will find a variation, and that there should be constantly a sum added or deducted. At a velocity of eighty feet per minute, for instance, a certain addition would be required to the revolutions; but after you get to 400 feet a minute, I think you would find that some of the anemometers would begin to register differently, and, therefore, this line [explaining by the formula] is not a straight line, but somewhat in the form of a curve. My observation leads me to believe that it is in the form of a hyperbola. This subject is of great importance to those whose duty it is to make an accurate measurement of the velocity of air in mines, and it is a very tedious business indeed to carry it out to perfection.

Mr. ATKINSON—I think Mr. Dickinson is under a mistake when he

states that, in Biram's anemometers, it is sometimes necessary to add and sometimes to deduct. The velocity of the wind is generally found to be equal to an expression of the form a R + b; where R represents the revolutions per minute, of the anemometer, and a and b are constants. There are five or six anemometers, by all of which the amount of the velocity is found by means of an additive, and do not require a deduction.

Mr. DICKINSON—Are any of these anemometers heavy, or are they all of that description?

Mr. ATKINSON—I have worked them all, and they all involve an additive: the wind force is as the square of the velocity. There is a curve shown, but it is very slight indeed.

Mr. DICKINSON—Are they all heavy anemometers?

Mr. DAGLISH—They are anemometers of all sizes. The mode in which the formula is obtained, and its action, is explained at length in the paper. The formula given will apply to any instrument, either heavy or light. By altering the multiplying constant, the line given by any anemometer can be brought on to the diagonal.

The PRESIDENT—I am afraid that time will not permit of our entering at any length into this interesting investigation. It is an extremely important one, and, as Mr. Daglish very properly says, next to the importance of knowing that there is a current of air in the mine, is that of ascertaining how strong that current is. As the theory and practice of ventilation forms one of the most important elements in the study of mine engineering, it is highly desirable that such a subject as this should be brought before the meeting, with a view to further investigation. I am glad to find that these gentlemen have taken up the subject, with a view of testing the accuracy or inaccuracy of the instruments in use, and I think it may properly be left in their hands to produce a more complete paper before the papers are printed, when the whole subject can be brought under discussion at the meeting fixed upon for that purpose.

CONCLUSION OF THE MEETING.

ULTERIOR ARRANGEMENTS AS TO PAPERS PRESENTED TO BE READ.

The PRESIDENT, after the reading of Messrs. Atkinson and Daglish's paper, said, I hardly know how to deal with the papers which are still to read. There is one by Mr. Daglish on "Shaft Tubbing and Walling;" one by Mr. Lever, and another by Mr. Charlton, on "Safety-Lamps;" and then there is Messrs. Atkinson and Coulson's paper, which treat on subjects of considerable importance, but I am afraid we shall have no time to read them.

Mr. MATTHEWS—It would be very desirable to hear Messrs. Atkinson and Coulson's paper read, but I do not think that it could be properly done within a quarter of an hour, and certainly we could not discuss it. It would hardly be doing justice either to the subject or to Mr. Atkinson to hurry it through. I am afraid there is not time enough to treat it with that attention which its importance certainly merits at our hands.

Mr. ATKINSON—I am perfectly willing that it should be printed without being read at all, or that it should be read at once. I am quite in the hands of the President and the meeting.

The PRESIDENT—It could not properly be printed without being read. It might be deferred being read till the next monthly meeting of the Institute, and so become part of the proceedings. Nor do I think that the adoption of such a course would be attended with any inconvenience, because I believe I am correct in stating, that the papers which we have already read, up to the time we came here, will, together with the proceedings of the anniversary meeting in August, form sufficient matter for the volume of 1861. Then, I think that the papers which have been read here will almost form another volume. This paper will, if dealt with as I propose, be printed along with others forming part of the volume of 1862, and would be in the hands of the members in a couple of months, and it would be open for discussion before the end of the year. I do not think it would be doing justice to Messrs. Atkinson and Coulson's, or Mr. Daglish's papers, that they should be read in a very imperfect manner

now, and at a time when no discussion can take place upon them. I should, however, be glad to take the sense of the meeting upon the subject.

Mr. ATKINSON—There is one advantage which, if it were possible to do so, would attend the reading of the paper now, and that is, that Mr. Coulson is present, and would be able to give any explanations that might be required.

The PRESIDENT—All that we can say about that is, that we hope when the paper comes on for discussion, Mr. Coulson will manage to be present. I presume the success which has attended this meeting will induce us to meet again in a similar way, to discuss the papers of this meeting, after they have been in the hands of the members, and to read other papers; and if so, we might enter into a discussion upon this paper after the members have had it before them, and quietly considered it over. No doubt Mr. Coulson will make an effort to be present on that occasion. He is very much employed on the Continent in sinking pits, and certainly no one in our district has had the experience that he has had, and therefore I hope that he will endeavour to be present when the paper is discussed.

Mr. COULSON—I am quite sure that it would take too long to discuss the subject now.

The PRESIDENT—Then I think we had better postpone the paper for the present.

THANKS TO THE MIDLAND INSTITUTE.

The PRESIDENT—Gentlemen, I think that it is only right and proper that before we separate we should return our best thanks to the Council of the Birmingham and Midland Institute, to which this building belongs, for the use of the room, and for the very handsome manner in which they have received us on the occasion of our visit to Birmingham. Without saying more, I beg at once that our best thanks be given to the Council and Members of the Birmingham and Midland Counties Institute.

The vote was carried by acclamation.

THANKS TO THE DEAN OF FACULTY AND MANAGER OF THE COLLEGE.

The PRESIDENT—There is also another public body to whom our thanks are due, and that is the Dean of Faculty and the Managers of this College, for the use of the room in which our models have been exhibited. I therefore beg to propose a vote of thanks to them.

Carried by acclamation.

CONCLUDING OBSERVATIONS.

The PRESIDENT—Now, gentlemen, I have only a very few observations to make to you on the conclusion of this most interesting meeting. I am sure it must have been most gratifying to every member of the Northern Institute of Mining Engineers, to have seen such a number of gentlemen present since we commenced our proceedings. The fact that such a number of gentlemen have been present shows the great interest which has been excited in this district, and nothing can better repay the trouble and pains which the Institute has taken, than to meet so many of their friends at this distance from the locality which is the principal theatre of their operations. It has far exceeded my expectations to have seen so large a number of gentlemen gathered together on this occasion, and I hope that, if it should be the pleasure of the members of the Institute, and for the convenience of particular districts, that we should meet next year in some different locality, such a meeting may be equally successful. I am sure that the gentlemen residing in Newcastle and its neighbourhood would be very glad to have the meeting held in any locality which may be thought most central, and most suitable and convenient for the members of the Institute. As president of the Society, and in the name of the Institute, I beg to return the gentlemen present, and those who have honoured us with their presence, our most hearty thanks for the honour they have done us by attending this meeting to the extent they have.

Mr. MATTHEWS—Gentlemen, before we separate, let me request the meeting to do an act of courtesy as well as an act of justice in returning our very best thanks for the service which Mr. Wood has rendered on this occasion, by so ably presiding over our discussions. Mr. Wood's known reputation as a man of science, as a man of large influence, and as a man of great authority upon all questions of practical importance, like those which we have discussed yesterday and to-day, entitle him to our warmest consideration. He has conducted the business of the meeting with that urbanity, that courtesy, and that intelligence which characterizes the whole course of his life; and we should be doing great injustice to him, as well as much discredit to ourselves, if we did not, before separating, present to Mr. Wood our best acknowledgments for the able and courteous manner in which he has presided over and conducted the whole business of the meeting. Gentlemen, I beg to propose that the thanks of the meeting be given to the President, Nicholas Wood, Esq., for the able manner in which he has conducted the business of the last two days.

Mr. Blackwell—I beg most cordially to second the motion.

The motion was then put by Mr. Matthews, and carried by acclamation.

The President—Gentlemen, I feel extremely obliged to you for the manner in which you have received the proposition of my friend Mr. Matthews, seconded by Mr. Blackwell. I certainly have devoted all the energies with which I am possessed in the advancement of those objects to which my friend Mr. Matthews has alluded, and especially of those for the promotion of which the Northern Institute of Mining Engineers was established. I have given all the time I could possibly spare to render it as an Institution as successful and as useful as possible. I thought that the formation of such an Institute, when it first commenced its operations, would be chiefly advantageous, as far as it could influence the improvement in coal mining, to the district in which coal mining was carried on to the greatest extent, namely, Newcastle-upon-Tyne. I hardly expected that it would ever meet with such success and such coöperation as that which has resulted in our meeting at Birmingham; and it is certainly most gratifying to me that such should have been the case. In conclusion, I can only say, gentlemen, that I am exceedingly obliged for the very flattering recognition which you have made for any slight services which I may have rendered to the Institute on the present most interesting occasion.

This having concluded the business, the meeting broke up.

NORTH OF ENGLAND INSTITUTE
OF
MINING ENGINEERS.

ANNIVERSARY MEETING, THURSDAY, AUGUST 7, 1862, IN THE ROOMS OF THE INSTITUTE, WESTGATE STREET, NEWCASTLE-UPON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

The PRESIDENT (after the business of the anniversary meeting had been disposed of) said, he had to bring before them the discussion of the papers of the Birmingham Meeting. They had issued a circular, that it was necessary that the authors of these papers should be present at such discussion; but there appeared to be only present the authors of two of the papers. Members would recollect that it was arranged at Birmingham that the discussion should be taken at the time, the parties all being present; but it was found that there was not time for the discussion of all the papers. As Mr. P. S. Reid and Messrs. Atkinson and Daglish were the only gentlemen present, he (the President) supposed that those authors whose papers were discussed at Birmingham thought such discussion was sufficient, as they were not present to-day. They would, therefore, take the discussion of the papers by Mr. Reid and by Messrs. Atkinson and Daglish.

DISCUSSION ON MR. REID'S PAPER ON TUBING BORE HOLES IN PASSING THROUGH QUICKSANDS, &c.

Mr. BOYD called attention to the word "first" on the drawings accompanying the paper. He wished to set Mr. Reid right. With all due deference to him, this was not the first time such a principle was made use of—the principle, namely, of using screws, and the description of tubing referred to—for the purpose of passing through water, sand, or

gravel, in boring. Mr. Ralph Maddison was engaged for the Urpeth Colliery, in 1844, and used an exactly similar description of tubing—malleable iron tubing, done with screws, and fitted together, and with the same face both inside and out. The hole went twenty-two fathoms through sand and clay, without coming to any rock stratification, and was perfectly successful. It came to the coal measures at the bottom of twenty-two fathoms, and proved the seam which was then searched for. The principle of withdrawing the tubes was also adopted. After Mr. Maddison had effected his purpose, he (Mr. Boyd) employed a small slot attached to a strong chain let down the inside of the tubes, and this slot falling out at the bottom of the tubes, by great power used at the top of the hole, he drew the whole twenty-two fathoms of tubing. He (Mr. Boyd), simply wished to set Mr. Reid right on the word "first." He did not mean to say Mr. Reid had not great credit in the successful manner in which he accomplished his boring at Kirklevington, but he thought the Institute should be set right as to the priority of the use of such a measure.

Mr. REID—Can you inform me where the tubing was obtained?

Mr. BOYD—At Birtley Iron Works.

Mr. REID—There is no such tubing as I used at that hole made in this district at the present moment; the distinction is, that it is the same as the locomotive boiler tubes, which *have not yet been made here.*

Mr. MARLEY—How are the tubes connected together?

Mr. REID—By screws, half-lapped into each other.

The PRESIDENT—You say it was not the same tube as Mr. Boyd mentions?

Mr. REID—Not the same.

Mr. ATKINSON—The one was with a vertical seam, the other without such a seam; I do not see that there is anything essentially different in the construction.

Mr. REID—There is this difference: that my tubing offers less resistance to tools going down through the strata.

Mr. MARLEY—It would appear that the difference Mr. Reid claims is in the joining of the tubes. His were screwed, while those used by Mr. Boyd and Mr. Maddison were not so. Those described by Mr. Boyd fitted together by a sort of overlapping joint, perfectly smooth in the face both inside and out, and were screwed together horizontally. Therefore, there is that distinction between the two; but otherwise there is no difference in the principle, and no difference whatever in the result, because there was a most perfect face both outside and inside.

Mr. BOYD—And water-tight.

The PRESIDENT—Do you think them equally fit for the purpose?

Mr. MARLEY—I think so, quite.

Mr. REID—It is quite clear, if I could have got such tubing at Birtley, I would not have gone to Birmingham for it.

Mr. BOYD—Did you make application for it?

Mr. REID—I did.

The PRESIDENT—If there is such a distinction between your tubes and those named by Mr. Boyd, your observation about their being the first used would be correct.

Mr. T. E. FORSTER—It would not be the first tubing used?

Mr. REID—I do not mean to say so.

The PRESIDENT—He says that particular tubing for bore holes was first applied at Kirklevington.

Mr. REID—It is that particular description of tubing first applied.

Mr. MARLEY—When the word is restricted simply to the mode of fastening the pipes together, it is correct.

The PRESIDENT—Mr. Reid may not have had before him that question. The great point for the Institute is, which of the two plans is the best. Mr. Marley seems to think there is no great difference between them.

Mr. MARLEY—I do not think there is a great difference; and I think the way Mr. Maddison's tubes were fastened together was more likely to be permanent than the present.

Mr. REID—Do you mean a rivetted tube is more likely to work well than a solid one?

Mr. MARLEY—It would be a solid one.

Mr. REID went on to state, that in the French mode of boring, as represented in the Exhibition, they had tubes precisely similar to those described by Mr. Boyd. The attention of Mr. Sopwith, and, he believed, Mr. Smythe, had been drawn to their defects, which were palpable.

DISCUSSION ON MESSRS. ATKINSON & DAGLISH'S PAPER ON THE VELOCITIES OF CURRENTS OF AIR IN MINES.

Some conversation next took place on the subject of Messrs. Atkinson and Daglish's paper.

Mr. ATKINSON said he had no further remarks to make on the matter.

The PRESIDENT thought the paper was a very ingenious and able one;

but, unless they could go into it fully, no off-hand observations would be of any avail. He thought it would be quite competent to go into the discussion in some shape, any time afterwards.

Mr. ATKINSON said, the general result they had come to after making a large series of experiments, was, that none of the anemometers gave correct results as to the quantities of air, but they had adopted means by which they could find a formula which applied to each anemometer; different constants had been found to be required for different instruments, depending on their construction, weight, direction, and so forth; and by applying the formulæ into which they entered, to the observations, they got the actual velocities, without which, the anemometers were comparatively useless.

The PRESIDENT remarked, that every anemometer differed in some respects from another, and thus produced different results. In consequence of friction, or construction, or something or other, they all varied, and they required that experiments should be made with each instrument, and from these they might deduce constants which would bring out a correct result. [Mr. ATKINSON—Quite so.] This was rather important, because hitherto, the general practice had been to assume that the anemometer was correct, and, of course, every gentleman must see the instruments could not be quite correct, made as they were, by different parties, and in some respects not strictly accurate, not to speak of the friction being variable. So far as he had read Messrs. Atkinson and Daglish's paper, it seemed to show very conclusively the necessity of an experiment being made with each instrument, for the purpose of obtaining a constant, which, on being applied thereafter, would produce a correct result; and he supposed, that by particular attention to what they had recommended, it was practicable to get out of every anemometer a correct result as to the quantity of air.

Mr. ATKINSON said, it was possible to find a rule for any anemometer, which would give correct results.

The PRESIDENT—You very conclusively prove that one anemometer varies from another, and records different results?

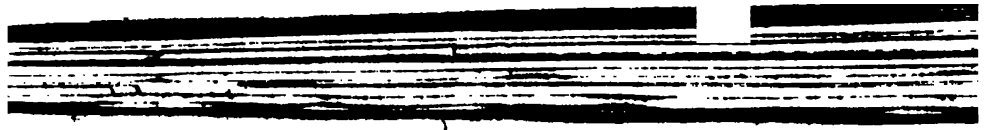
Mr. ATKINSON—Just as much as human faces vary from each other.

The PRESIDENT—And that it is necessary you should, in using them, go a little further and ascertain the constant peculiar to each instrument, so as to produce a correct result? It is very important the Institute should know this, whether they practise it or not. If they want strict accuracy, you have shown them how to obtain it.

Mr. DAGLISH said, there was one very satisfactory result, that almost all the Biram anemometers, of one size, had a general resemblance to one another, though not strictly accurate. One of the diagrams accompanying the paper, gave a great number of experiments with the small anemometer, almost all running on the same line, and a general formula might be given for that particular size of instrument. There was another interesting point, that the anemometers continued correct. The fact of their being dirty or clean did not affect their accuracy, provided they did not get broken, so that, if the constants were once found, they would be always true for that instrument.

The discussion then dropped, the PRESIDENT remarking, that he thought their Birmingham volume would, with the addition of this discussion, be a very respectable one.

After a vote of thanks to the Chairman, the meeting broke up.



Catalogue of Institute Library.

CATALOGUE.

A

Accum, Fred., A Practical Treatise on Gas Light. 1815.

Annales des Travaux Publics de Belgique. Tome 12. 1853–54.

Ansted, David T., An Elementary Course of Geology, Mineralogy, &c. 1850.

Agricolæ, Georgii, Kempnicensis Medici Ac Philosophi Clariss De Re Metallica, libri xii. 1657.

Arts et Metiers. Vol. X., 1768; Vol. XI., 1774; Vol. XII., 1777. Art D'Exploiter la Houille.

Atlas de la Richesse Minérale. Par M. le Baron Héron de Villefosse. Nouveau Tirage. *Paris*, 1838.

B

Bainbridge, Wm., A Treatise on the Law of Mines and Minerals, 1856.

Bakewell, R., An Introduction to Mineralogy. 1819.

Ditto, An Introduction to Geology. 1833.

Bell, J., Collections relating to the History of Coal and Mining. 21 vols. Presented by Thomas J. Taylor, Esq.

Belt, Thomas, on Mineral Veins: an Enquiry into their Origin, founded on a Study of the Auriferous Quartz Veins of Australia. 1861. Presented by Thomas Belt, Esq.

Brard, C. P., Elemens Pratiques d'Exploitation. 1829.

Brongniart, A., Tableau des Terrains qui Composent l'Ecorce du Globe. 1829.

Ditto, Traité Elémentaire de Minéralogie, 2 vols. 1807.

Bourne, John, C.E., A Treatise on the Steam Engine. 1855.

Buddle, John, First Report of a Society for preventing Accidents in Coal Mines. 1814. 2 copies. Presented by P. S. Reid, Esq.

C

Catalogue of the Minerals and Fossil Organic Remains of Scarborough. 1816.

Chabannes, Marquis de, On Conducting Air by Forced Ventilation. 1818.

Chalmers, James, C.E., on a Channel Railway. 1861.

Civil Engineers, Proceedings of, 16 vols. 1842–59.

Ditto, Catalogue of Books in Library of. 1850.

Clegg, Samuel, Jun., A Practical Treatise on the Manufacture and Distribution of Coal Gas. 1841.

Combes, M. Ch., Traité de l'Exploitation des Mines, 3 vols. 1844–5.

Ditto, Ditto Ditto Atlas. 1847.

Conybeare and Phillips, Outlines of the Geology of England and Wales. 1822.

D

Dalton, John, Meteorological Observations and Essays. 1834.

Ditto, A New System of Chemical Philosophy. Part I., vol. II. 1827.

Ditto, Ditto Ditto. Part I., 2nd edition. 1842.

Davy, Sir H., on the Fire Damp of Coal Mines. 1816.

De la Beche, Henry T., Report on the Geology of Cornwall, Devon, and West Somerset. 1839.

Ditto, A Geological Manual. 1833.

Doursther, H., Dictionnaire des Poids et Mésures. 1840.

Dunn, M., View of the Coal Trade and History of the Steam Jet. 1844. Presented by M. Dunn, Esq.

Ditto, Winning and Working of Collieries. 1840. Presented by M. Dunn, Esq.

E

Explosion, Hetton Colliery. 1860.

F

Faujas-Saint-Fond, B., Voyage en Angleterre, en Ecosse, &c. 2 vols. 1797.

Fenwick, Thos., Essays on Practical Mechanics. 1824.

Flötz-Karte des Steinkohlen-Gebirges bei Beuthen, Gleiwitz Myslowitz und Nikolai in Ober-Schlesien, *in sheets*. Dr. von Carnall. 1860.

Forster, Westgarth, Section of Strata from Newcastle to Cross Fell in Cumberland. 1821.

Fossil Fuel and Collieries, History of. 1841.

Feier, die, des Zehnjährigen Stiftungsfestes des Architecten und Ingenieur-Vereins für das Königreich. *Hannover*, 1861.

G

Gaea Norvegica, von mehreren Verfassern herausgegeben von B. M. Keilhau, &c. 1838.

Geological Facts and Practical Observations, by E. Mammatt. 1834.

Girardin and Burel, Rapport sur l'Exposition Universelle de 1855. *Paris*, 1856.

Greenwell, G. C., A Practical Treatise on Mine Engineering. 1855. Presented by G. C. Greenwell, Esq.

Geological Survey of the United Kingdom. 8 parts. Presented by Sir R. I. Murchison, from the Geological Survey Office.

Geological Survey of Great Britain, &c. 1856. Presented by Sir R. I. Murchison, from the Geological Survey Office.

Geognostische Karte von Ober-Schlesien entworfen von R. v. Carnall.

H

Hales, Stephen, A Description of Ventilators, whereby great Quantities of Fresh Air may with ease be conveyed into Mines, &c. 1742.

Hall, T. Y., Treatise on various British and Foreign Coal and Iron Mines and Mining. 1854. Presented by T. Y. Hall, Esq.

Henckel, J. F., Pyritologia; or a History of the Pyrites. 1757.

J

Jars, M., Voyages Metallurgiques. 3 vols. 1774, 1778, and 1780.
Ditto, Ditto, 1st vol. (Angleterre). 1774.

Johnstone, Alex. Keith, Physical Atlas of Natural Phœnomena.

K

Kirwan, Richard, Elements of Mineralogy, 2 vols. 1796.

L

Leithart, John, Practical Observations on Mineral Veins. 1838.

Lesley, J. P., Manual of Coal and its Topography. 1856.

Literary and Philosophical Society of Newcastle, Transactions of, 6 vols, 1793 to 1845. Presented by E. F. Boyd, Esq.

Literary and Philosophical Society of Newcastle, Catalogue. 18
Presented by the Society.

Ditto Ditto, Supplementary C
logue of, 1829. Presented by the Society.

Ditto Ditto, Catalogue. 1848. I

Literary and Philosophical Society of Manchester, Memoirs of, 15 v
Presented by the Society.

Lyell and Faraday, Report on the Explosion at the Haswell Collie
1844.

M

Machines à Vapeur, Règlement de Police et Instructions. 1854.

Mammatt, E., Geological Facts and Practical Observations. 1834.

Mechanical Engineers, Institution of Birmingham, Proceedings of, 3 v
1849, 1856, and 1860. Presented by the Institution.

Mechanical Engineers, Proceedings of, 6 vols. 1848, 1859.

Meteorological Tables, from the Register of the Lit. and Phil. Societ
Newcastle. 1849 to 1851. Presented by P. S. Reid, Esq.

Metropolitan School of Science, Prospectus of, 7th Session, 3 co
1857–8.

Mining Journal, 11 vols. 1847 to 1852. Presented by Wm. An
son, Esq.

Moore, Ralph, The Ventilation of Mines. 1859.

Morand le Medecin, L'Art d'Exploiter les Mines de Charbon de Te
Vol. X., 1768; Vol. XI., 1774; Vol. XII., 1777.

N

Natural History Society of Newcastle, Transactions of, 2 vols. 1
to 1838.

North of England Institute of Mining Engineers, Transactions of, 11 v

O

Oberschlesien's Gebirgsschichten oder Erläuterungen zu der Geogr
tischen Karte von Oberschlesien, von Rudolph von Carnall.

P

Pambour, Comte de, Theory of the Steam Engine. 1839.

Ditto, A Practical Treatise on Locomotive Engines. 18

Peclet, E., Traité de le Chaleur considerée dans ses applications. 18

Ditto, Ditto Ditto (planches). 18

Peclet, E., Traité de le Chaleur considerée dans ses applications. Supplement.

Peclet, E., Nouveaux Documents relatifs au Chauffage et à la Ventilation, &c. 1854.

Phillips, John, Illustrations of the Geology of Yorkshire:—
Part 1.—Yorkshire Coast, 1 vol. 1835.
Part 2.—Mountain Limestone District, 1 vol. 1836.
Ditto, Ditto, Palœozoic Fossils of Cornwall, Devon, and West Somerset, 1841.

Physical Atlas of Natural Phœnomena of the Globe, by A. K. Johnstone.

Playfair, Prof., A Comparative View of the Huttonian and Neptunian Systems of Geology. 1802.

R

Réceuil de Mémoires et de Rapports des moyens de soustraire l'Exploitation des mines de Houille, aux chances d'Explosion. 1840.

Report on Guérin's Self-acting Railway Brake. 1857. Presented by M. Guérin.

Report on George Stephenson's Claims to the Invention of the Safety Lamp. 1817.

Report on Accidents in Coal Mines. 1835.

Rogers, Ebenezer, Description of a Ventilating Fan at Abercarn Collieries, &c. 1857.

Ronalds and Richardson, Chemical Technology, 2 vols. 1855. Presented by Messrs. Ronalds and Richardson.

Royal Institution of Great Britain, Notices of Proceedings, &c., from 1851 to 1859. Presented by the Royal Institution.

Ditto, List of Members, Officers, &c., with the Report of the Visitors for the year 1853. Presented by the Royal Institution.

S

School of Mines, Records of. 1852-3.

Scrivenor, Harry, History of the Iron Trade. 1854.

Smeaton, John, F.R.S., Reports on Civil Engineering, 2 vols. in 1. 1837.

Sopwith, T., An Account of the Mining Districts of Alston Moor, &c. 1833.

Statistiques de la Belgique, Mines, Usines, Minéralurgiques, Machines à Vapeur, &c. 1839 à 1844.
Ditto, Ditto. 1845 à 1849.

Statistiques de la Belgique, Mines, Usines, Minéralurgiques, Machines à Vapeur, &c. 1850.

Ditto, Rapport au Roi. 1842. These four works were presented by the Ministre des Travaux Publics from the Belgian Government.

Stephenson, George, Safety Lamp. 1817.

T

Taylor, R. C., Statistics of Coal. 1848.

Tredgold on the Steam Engine—Stationary, Locomotive, and Marine, 4 vols. 1852-3.

U

Uebersicht von der Production der Bergwerke Hütten und Salinen in dem Preussischen State im Jahre, 1855-56-57-58-59.

W

Werner's New Theory on the Formation of Veins. 1809.

Williams, John, Natural History of the Mineral Kingdom, 2 vols. 1789.

Wood, Nicholas, Safety Lamps for Lighting Coal Mines. 1853. Presented by N. Wood, Esq.

Y

Young and Bird's Geological Survey of the Yorkshire Coast. 1822.

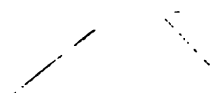
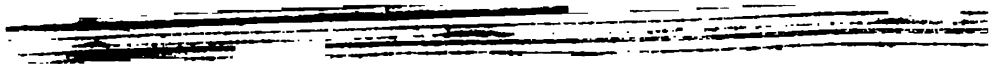
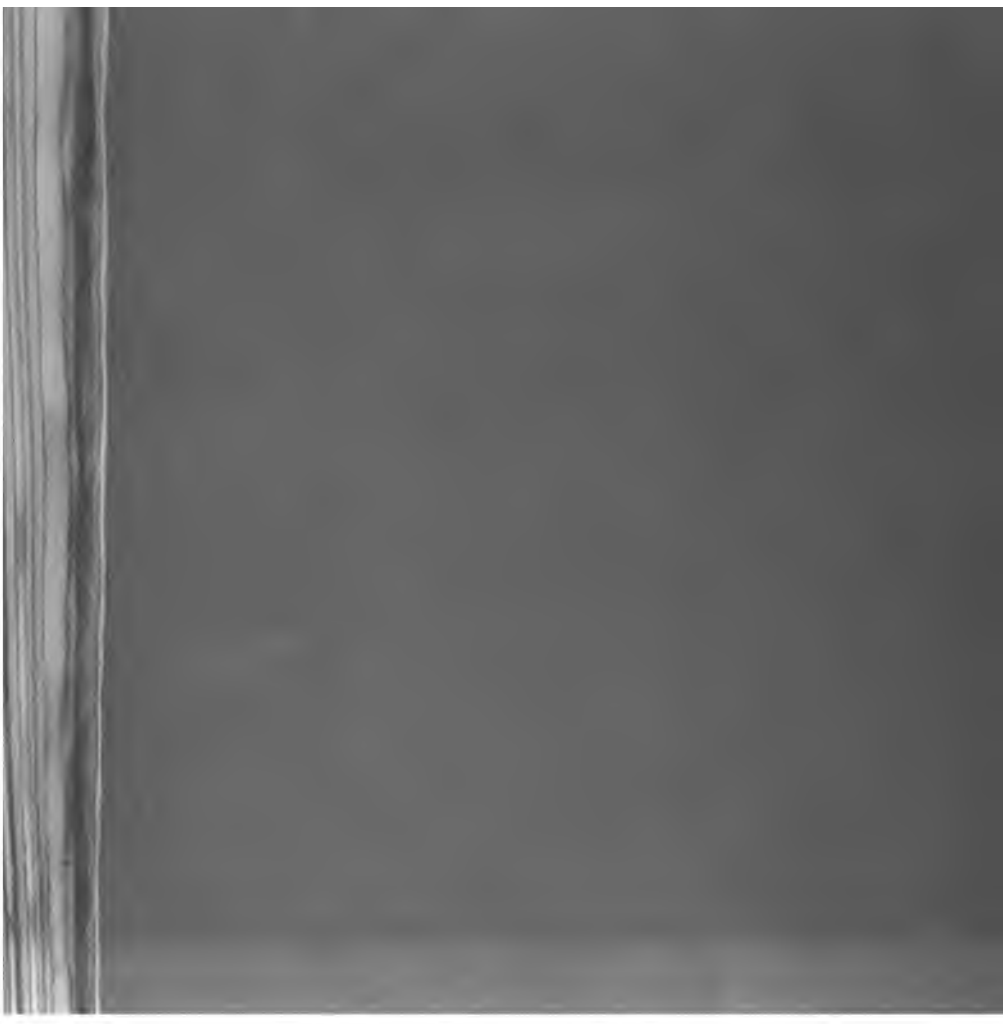
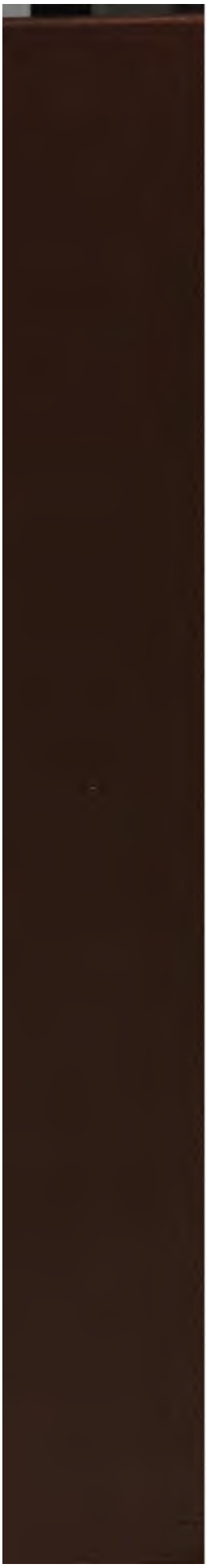
Z

Zeitschrift für das Berg-Hütton-und Salinenwesen en dem Preussischen Staate, 3 vols. 1854-5-6. Rudolph von Carnall.

Zeitschrift des Architecten und Ingenieur-Vereins für das Königreich. *Hannover*, 1861.

DIRECTIONS TO BINDER.—VOL. X.

Cancel Blank Page in Part IV.

Directions for placing Maps, Plans, &c.

	PAGE.
No. 1 Plan	25
No. 2 Plan	33
Longitudinal Section	34
Map of the Rivers, Ports, &c., of the Great Northern Coal-field	41
Mr. Aytoun's Patent Safety Cage	83
The Bristol Coal-field	97
Section of the River Avon (North Side)	98
Sections of Park Field Pit, &c.	100
Map of the Coal District in the Counties of Derby and Nottingham	117
Section of the Strata in the Derbyshire Coal-field	119
Plan of the Working and Ventilation of Shipley Colliery—Soft Coal Seam	125
Do. do. Hard Coal Seam	126
Buxton's Furnace Signal and Register	133
Plan of Cinderhill Colliery	149
Plan, showing New Red Sandstone, Limestone, &c.	150
Diagram of Method of Working Moira Main Coal	161
Diagram of Gate Road	164
Section of the Thick Coal at Heath Colliery	184
South Staffordshire Thick Coal Workings—"Pillar and Stall"	188
Section of Park Head Colliery Thick Coal	195
Method of Tubing Bore-holes	199
No. 1—Gunpowder Smoke, &c., &c.	215
No. 2—View of Whirling Machine	217
No. 3—Comparison of Governors	219
No. 8—Comparison of Anemometers	228
Henaut's Anemometer	238